Bachelor Degree Project

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HIGH-LEVEL LANGUAGE DESIGN

for IMMA-Virtual Driver DHM Research

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Beñat Garay García

Supervisor: Lars Hanson
Co-supervisor: Dan Högberg
Examiner: Peter Thorvald

Assurance of own work

This project report has on 6th of June of 2015 been submitted by Beñat Garay to University of Skövde as a part in obtaining credits on basic level G2E within Product Design Engineering.

I hereby confirm that for all the material included in this report which is not my own I have reported a source and that I have not – for obtaining credits – included any material that I have earlier obtained credits within my academic studies.

Beñat Garay García

Abstract

The growing implementation of ergonomics in the automotive sector sets high demands on Digital Human Modelling (DHM) functionalities towards the simulation of more realistic environments and the reduction of physical model dependency. During the current degree project a leading element that smartly assembles DHM usage (implementation of high-level commanding languages) was designed, revolving around the industries' needs which were gathered and interpreted in order to organize current functions in this language and suggest new complementary functions that would create a language environment suitable for non-expert users. This was achieved by focusing in an intuitive word-function structure, the proposal of defaults and other tools that aid users with different kinds of expertise. The need for realism of simulations was assessed by the language design especially by designing means to coordinate synchronic manikin-actions.

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Glossary & Abbreviations

WP3
Work Package 3
The current project

It refers to the initial description of the current project as defined by the Virtual Driver Project, which encompasses several parallel projects of which some of them are "Work Packages" like the present. This *WP3* contraction is mainly used throughout the report when the initial definition of the project is wanted to be remarked.

WP2
Work Package 2
Pamela Ruiz de Castro's project

WP2 stands for Pamela Ruiz de Castro's project also carried within Virtual Driver, "*Seating Comfort analysis for Virtual Driver Research*", as named by the Virtual Driver Project encompassing different projects. The acronym is used to shortly refer to a work that although it may be relevant for the current one, as it is parallel to it, it will be unfinished in the course of the present project, making it difficult to reference it otherwise.

IMMA
Intelligently Moving Manikin
DHM software involved in the current project

The IMMA Digital Human Modelling software was born in 2009 thanks to the join of University of Skövde, Fraunhofer-Chalmers Research Centre, Chalmers University of Technology, Volvo AB, Volvo Cars and Scania. It is able to predict both postures and motions by the use of mathematical algorithms instead of the usual motion and posture captures.

1 Introduction

The present chapter aims to introduce the foundations on which the current bachelor's thesis was carried out. Thus, background and context matters, the purpose of the project and some limitations will be discussed.

1.1 Background & context

Bhise (2012) states that while the implementation of ergonomics in vehicle design has improved user comfort, convenience and safety substantially in the last three decades, the current rapid technological development makes the future needs for assessments in this field even greater.

Ergonomic assessment in vehicle industries is usually aided by Digital Human Modelling (DHM) especially at early stages in the design process. However, existing competent alternatives require expert usage-skills; in addition, the features they offer are often insufficient considering ongoing and future demands in the sector. The renowned German ergonomist Heiner Bubb suggests some prospective features the sector is increasingly valuing for DHM:

"*At some point we will be able to check the entire ergonomics in the vehicle digitally. New software, new studies and new applications will pave the way for us to achieve this. [...] The primary new issues are automated motion and cognition. And for me, the vision behind this is RAMSIS someday tackling completely situation-dependent tasks. For example: 'Drive on the freeway and turn on the radio'*." (Human Solutions, 2013, p.3, p.11)

The hereby reported design research project was concluded within the field of vehicle user ergonomics oriented DHM, this being part of a larger research, Virtual Driver, which encompasses several collaborating entities: Fraunhofer-Chalmers Centre, Högskolan i Skövde, Scania, Volvo Cars and Volvo AB.

Virtual Driver's general purpose is IMMA (Intelligently Moving Manikin) DHM software by Fraunhofer-Chalmers Centre (2009-2014) to reach a version that can ambitiously assess user ergonomics for car, truck, bus and construction vehicle users from early design stages. It is to consider that IMMA was originally built within the previously mentioned collaborator's alliance aiming ergonomic verification of workers in vehicle assembly lines, as Hanson et al. (2014) explain.

It should be pointed out that IMMA, together with a parallel project called CROMM (tackling muscular biomechanical simulations), is distinguished for the use of sound mathematical solutions, which open a broad range of new

horizons like kinematic analyses in the near future. On the contrary, other known virtual tools in the area are founded on postural and motional recorded data as a very central element for the software's working core.

1.1.1 High-level language and IMMA

Since this project targets the creation of a new high-level language design for IMMA, it should be first made clear what is meant with high-level language. High-level, in the present context refers to the level of abstraction. In fact, these languages would be in a similar level of abstraction of the terms we could use to generally and briefly describe what a manikin is doing when a simulation being run. Notice that as Coughlan (2014) mentions, well-known programming languages like C, C#, Java, Pascal, Basic or COBOL, are high-level languages. Nonetheless, it is not a programming language what it is being designed here, but a language that acts itself as a user interface environment resource between the features of the software (IMMA) and the user, therefore being much higher in abstraction than any of the mentioned program languages.

Thus, this language is the hierarchically structured compound of words that encompass different actions and options that will call to software's current resources, functions and capabilities in order to set the different elements of the scene (consult chapter 2.4), including objects, paths, manikins and acting geometries so that simulations of manikin-tasks can be performed. Therefore, considerable knowledge on these elements and features of the software in which the language design is to be implemented (i.e., IMMA) is crucial to succeed in the design of it. These relevant characteristics are addressed in chapter 2.3.1.

Alike some other DHM software and as Mådberg et al. (2014) explain, IMMA currently has a high-level language tool which allows ordering abstract commands to the manikin rather than having to plan every single joint's translation and rotation individually throughout different time frames; the tool is presently called 'Language Operation Editor'. However, this project would not have any reason for being without recalling the previously stated fact that the current IMMA version and its language, consequently, are not designed to assess vehicle-user tasks but vehicle-assembly worker's tasks. For this reason, adapting the capabilities and features of the software in the language design for vehicle-user oriented workflow will be the catalyst to achieve the aims this project is proposing.

1.1.2 Other DHM in the area of IMMA

There are several software alternatives in the DHM field when it comes to assess user-vehicle ergonomics. However, due to industries preferences and characteristics of some of the software, the ones that are going to be dealt with in the current project (in addition to IMMA, of course) are mainly *Ramsis* and *Jack*, and secondarily *Delmia Human*.

Jack can be considered as a suitable benchmark when it comes to the language due to its leading *Task Simulation Builder* (manikin commanding high-level language), which is, as IMMA's current one, fully oriented to worker task assessment. Jack's *Occupant Packaging Toolkit* (including numerous SAE standards and car-centred ergonomic applications) was also tested. However, even though it could be considered as quite complete, as mentioned in *WP2 (check glossary)*, the default seated postures are centred on seated work tasks. Thus, particularly when referring to vehicle ergonomics, this software seems not to be as widely accepted in the sector as other.

On the contrary, Ramsis seems to be the preferred software in most collaborating entities. The software is completely vehicle oriented, and because it is much more settled down in the vehicle industry, some of its features are very specifically oriented to assist vehicle ergonomics. Nevertheless, it was noticed that Ramsis does not have any manikin-task commanding language (the "Task Editor" name of one of its functionalities can be misleading in this regard). Therefore, and considering that collaborators were going to show their usage of it, its previous analysis was not as prioritized as Jack's. In the end, knowing better different software avoids biasing of particularly one of each when implementing new ideas.

Delmia Human is also settled in one of the collaborating entities. However, it was confirmed in the first workshop with them that it lacks many features and several modifications had to be done to the software just to fulfil a bare pass in their demands. For this reason, it was not further analysed.

1.1.3 A specialized area

It is also important to be aware that the field in which the project is held involves specialized concepts, terminology, standards and an essential need of understanding the software on which this project revolves around. Thus, chapter 2 that follows will cover some essential aspects that will address to build a frame of reference to understand the consequent design decisions and in parallel, prevent the reader from possible confusions.

1.2 Purpose & objectives

The general aim of the Virtual Driver project is to meet industries' needs regarding DHM in a new version of IMMA oriented to vehicle-user ergonomics. In this approach, reliability and repeatability of results, usability and avoidance of user's subjective criteria that affect outcome are essential.

As for the present project, the scope focuses in the design of a high-level instruction language for the ongoing development of IMMA-Virtual Driver to simulate manikin-tasks that vehicle industries (cars, busses, trucks and construction vehicles) demand, and inspire other solutions for the future. Moreover, the capabilities or features of IMMA through the new language should be compared with other software. Jack was the software considered most adequate for the comparison, due to its TSB and OPT functionalities explained before (and more in detail in chapter 2.3.2).

The high-level language should preferably:

- Be easy and intuitive to use for new non-recurrent users mainly when it comes to setting manikin actions.

- Gather and interpret the industries' specific needs in relation to what the high-level language can provide or facilitate. Apply the identified needs in the language as far as limitations of the project allow.

- Guarantee the possibility to set the manikin to perform all the occupant packaging tasks that vehicle industries usually ergonomically evaluate through this kind of tool and as far as possible new tasks that they would find advantageous to evaluate; these prioritized as follows:
    - Primary driving tasks (r*equired*)
    - Secondary occupant packaging tasks (*demanded*)
    - Visibility related manikin-setting (*highly wished*)
    - Ingress/egress and vehicle service (*if there is time*)

- Ensure good balance in its design, meaning that the set of available instructions conforming the core of the language (e.g., 'steer wheel') that will allow users create complete operations will optimize mainly these two rival aspects: a reasonable amount of available instructions (i.e., not too crowded of different commands in a same level) vs. sufficiently specific and well-organized instructions that will cover the presumed big range of required particular actions allowing sufficiently straight-forward/intuitive commands.

- Help both configurability and repeatability. This can involve areas that surround the language like: the design of criteria and examples for defaults and configurability options, external management tools for simultaneous instructions and/or the implementation of easy and fast input in the language display environment. Although this it is not strictly central to the project it

should help building a highly automatable and repeatable workflow as well as fulfilling industries' configurability demands according to their own particular needs. It will also open a way for future improvements and further inspiration.

- Be self-evaluated by a demonstrator, comparing its performance with the traditional (i.e., manual) operation of the manikins by employing software demonstrators that implement the designed language versions. Demonstrators are to be built by the original programmers along the current project, and if not possible, explanatory demonstrators approved by them should be showed.

*Some of the analysis/outcome that is not expected is explained in chapter 1.4.1

1.3 Limitations

Most limitations have been found during the course of the project and been dealt with in order to come with solutions:

- The high dependency for the language of input modes, current capabilities, user interface, toolkits, etc.
- Lack of time compatibility for the implementation of the concepts concerning the development stage and pace of IMMA-Virtual driver and the shorter time span of the current project.
- Unreliable, inaccurate or unavailable literature information for specific needs of the industries regarding the present objectives, creating some dependency on the external collaborator's input.

1.4 Overall design strategy

This section will cover design strategy that was followed and determines some guidelines for methods that could be used, having as starting point the initial conditioning and characteristic features of the project.

1.4.1 Differentiating aspects of the project

Even though not explicitly, it has been made clear so far in this report that this project cannot be categorized as a regular product design project. Some of the

intrinsic aspects that *WP3* (see Glossary) presented in relation to the design methodology and related implications are described as follows:

- *There is not a physical product to be designed*: the current project should remain in the area of a software environment. While physical means of input, e.g., *Kinect* (https://www.youtube.com/watch?v=4FoeydgNjRU) or *Oculus Rift* are starting to be implemented in the field, the development of methods for the implementation of these or similar or technologies is not in the scope of the current work. This implies that any design methods exclusive for physical product design are not contemplated.

- *The design for appeal towards a specific market segment's taste is not a priority*: if any user interface representations are created in order to demonstrate concepts or propose complementary tools, there is not a particular user-sector whom to create "special" experiences to, when it comes to pure aesthetics (rather than functional). Therefore, although it is an area that should be take care of in other project or work package thoroughly, as for the current, desire generating related methods for graphic interfaces will not considered.

- *The definition of the work is rather narrow:* there are some design projects where in the beginning even the type of outcome product is unknown, or where even the problem can be solved without requiring a product but a service or other solution instead. This is absolutely not the case, and such extreme flexibility is not expected here since this is just a part of a larger research project, Virtual Driver. Therefore, the creative potential of the project lies in the interpretation and implementation of the industries demands, so that a way to fulfil future needs can be built.

1.4.2 Defining a design strategy

The main pillar in which this project is settled is the discovery, interpretation and implementation of vehicles industries needs that affect DHM ergonomic evaluations, more concretely in what an instruction language could potentially handle. Thus, interviews, meetings, workshops and/or focus groups with collaborating entities are central and unmissable. In addition, the timing and context of the project does not allow very roundabout seeking of alternative solutions as previously suggested.

Cross (2008) mentions that usually, modern design work is responsible of dealing with high-risk implications associated to mass production, costs and safety, therefore not allowing the designer to make mistakes, needing thus an extremely detailed design plan. In the current work, though, this principle does not apply, since software can be updated any moment and what is more, the

outcome will not be the final product of the larger project, but a considerable source in which innovations will be inspired or based on, instead.

This is compounded by the a presumable unfamiliarity in the field of a very specialized area, which awards a reason of being to the very first sub-stage “Contact” described next. All this involves that the methods cannot be foreseen in detail generally speaking. Adding to this the nature of the project described so far, it can be presumed that methods will not be very varied and that some of the procedures will be based on trial and error, both with the collaborating companies and with the software developers.

Bearing all this in mind, the chosen strategy is a general one, containing exploration, generation and evaluation phases. The communication of the results is not so much a “showcase” to sell the product in this case, but the product (language) being demonstrated and explained (with graphic aids). In the following lines methods for the initial phase are described, whereas the ones regarding generation, development and evaluation are explained in the corresponding chapters, i.e., chapter 4 and chapter 5.

1.5 Methods in exploration phase

In this section, methods employed in phases prior the concept development are described, this is, methods regarding exploration, stage that encompasses a contact phase due to the context of the project and an analysis phase, as usual.

1.5.1 Contact

Keeping in mind the unfamiliarity with the area mentioned before, this phase is aimed to acquire enough familiarity within DHM in automotive ergonomics, high-level language design in this area and related aspects in order to be able to carry out further research.

Approach to IMMA and initial testing

On the one hand, IMMA software and especially its language should be well understood, having considerable command on it. In this regard, IMMA was tested and tried to perform some of the actions that the language was not designed for originally. This way, the software could be learned and at the same time tested to seek for lacking needs and features that are important to take into account when it comes to resources that the language needs to call and coordinate.

In the beginning the manikin was tried to be set in a seating position and trough different constraints try to work out in a rudimentary way how

these constraints should work so that they can be automatized in the language. Later on, different tasks like steering the wheel or moving the shifter around were manually performed or using the current worker oriented language when possible, in order to see what are the limits of the current available language when it comes to sitting occupant packaging tasks.

Many results from these testing that were found too varied, full of subtleties, and very difficult to gather in some tangible results were an important part of the background knowledge for the designer that can be noticed later in the questions and issues tackled in the different workshops more practically.

Tangible results were of course gathered. However, it is about more overall understanding of the general features of IMMA that are relevant for the language design. This could be noticed in chapter 2.3.1.

Initial literature research

A first approach to the literature research was also done with similar purpose of familiarization and determination, in the topics of Vehicle ergonomics and related DHM. Although some standards, concepts and terminology might not be used, it is important to get to know them in order to understand the logic behind them, how things have been done so far, and so forth. Many of this information form just a mental framework which is necessary, but that does not intend to come with any direct output for the research, and will not be reported in the results' phase, since any outcome of it will be reflected in the following sub-stage's results.

This stage was also intended to include visits to collaborating companies, in order to perform second thorough focus groups with all collaborating entities, but eventually it was not possible to know their working environment and primary needs in the time this contact phase was supposed to take place, and eventually only one focus group could be performed after the three study visits held through the Analysis phase.

1.5.2 Analysis

This exploration sub-stage is mainly aimed to get better understanding of the field with literature research, and analysing more in detail the features of IMMA and other software that can be inspiring or useful for the new design, in order also to improve preparation and realization of workshops with suitable experts at the collaborating companies later on. Initial study visit meetings (mentioned in the previous point "Contact") were delayed; therefore, this stage encompassed those study visits (enabling to set the specifications with which the stage should

close), and initially planned workshops were moved to the “Generation” phase as an evaluation tool to improve concepts and propose upgrades for the future.

IMMA testing

Testing in the current stage was done more thoroughly to complete previous stage’s with similar procedure, but in this case, as more detailed trials were carried out a constant conversation with IMMA software developers was kept, since the more complex the tasks were tried out, the more difficult it was to make out whether it was a bug of the software or results that are not expected from the software (see Figure 2.2).

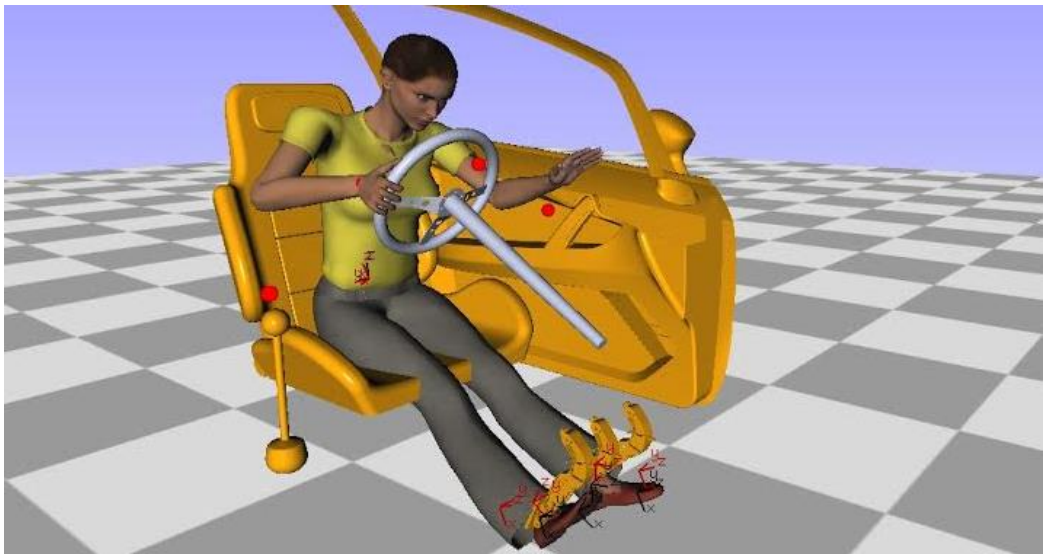

Figure 2.2 Test trials in current IMMA version simulating driving tasks.

Jack testing

Competitors’ software is also to be learned to some extent to have a general idea of what are the features that can be most interesting and have some benchmark. This was made for Jack 8 (TSB and OPT, see chapter 2.3.2) mainly, since its Task Simulation Builder (especially) and Occupant Packaging Toolkit were considered leading benchmarks for the current purpose.

Jack (general) user-guide was generally scanned and parts related with the language and aims of the current design (e.g., animation, easy snapping, visibility…) were read more in detail.

The user-guide for the Task Simulation Builder was entirely read and all included tutorials were performed so that the main capabilities of it were understood and embraced.

The same thorough read and tutorial performing was carried out with Occupant Packaging Toolkit.

Once finished, results were gathered. Only interesting features in relation to the language design are mentioned in chapter 2.3.2.

Study visits

In the current study visits, each collaborator was responsible to organize a workshop were they would show their workflow in general and particularly with the DHM software they use. All the visits were coordinated for both *WP2 and WP3* therefore answering matters from both projects that were sent in advance. These questions are included in the appendixes.

Workshops were audio recorded so that details would not be missed and the focus during the interview could be in asking on-the-go questions.

2 Theory background

The present chapter aims to explain common concepts in the field of Digital Human Modelling and recurrent standards and terminology of automotive ergonomics as well as some high-level language design oriented principles. In addition, capabilities from the studied software including current IMMA and Jack 8 (with TSB and OPT) will be included in this section. Thus, a good understanding on the some of the basic principles around which the results are founded in is to be obtained.

2.1 Digital Human Modelling

Digital Human Modelling (DHM) is known as a digital representation of the human body in a simulated virtual environment which aims to allow analysing, calculating and therefore, foreseeing a wide array of matters where the body performance or safety is involved, from ergonomics of products and workplaces to applications in the field of medicine. This enables engineers reducing or even getting rid of the dependency of physical prototypes which can be very expensive and less flexible, especially in early design stages (Duffy, 2008).

2.2 Occupant packaging

In the automotive industry, the expression “occupant packaging” refers to the activities and location of components and systems in the vehicle space, including occupants that must be accommodated together with all these elements in the vehicle. Design considerations for the development of the occupant packaging can be grouped in entry/egress, seat comfort, hand and foot controls, visibility of interior and exterior, storage spaces and vehicle service and maintenance (Bhise, 2012).

When it comes to the interaction of the driver (and possible passengers) in the vehicle, there are some standardized dimensions. Next, the ones considered basic and relevant for the understanding of the development of the new IMMA-Virtual Driver’s language are described as in Bhise (2012). After each description comments are also made regarding considerations of each of them regarding the current project:

- **Accelerator Heel Point (AHP**): it is the point in the shoe that touches the vehicle floor when the foot is heel supported and laying on the accelerator pedal, being the foot coplanar with the pedal plane (see Figure 2.1).

  This point is most often used as the principal reference for all the measurements, both in SAE standards and in most of the collaborating entities workflow.

  The idea of AHP, in addition to other non-standard heel points has been also implemented (see chapters 2.3.1 and 4) as a resource for assessing different pedals.

- **H-Point and SgRP:** the H-point (hip point) is the imaginary point in which the upper body and the legs would articulate around, where “back line” and “thigh line” would intersect. The SgRP (seating reference point) is a widely used point which is a specific location of the H-point near when the seat is near its rearmost position in the seating track, usually at the 95^{th} percentile of the horizontal distance (X_{95}) of the H-point (measured from AHP), as recommended by SAE.

  The H-point has been confirmed as an essential point to locate the passengers (or manikins in DHM) in the seat (see chapters 2.3.1 and 4).

- **Ball Of Foot (BOF):** this is the assumed as central pressure point of the foot in the accelerator pedal plane, which corresponds to the top portion of the driver’s foot.

  This point (more accurately the concept, rather than a static measurement from AHP) has been useful for the implementation in the language workflow (see chapters 2.3.1 and 4); it was considered as a moving (sliding) point in the case of pedals where there is heel support, having thus a dependence on the pedal plane angle (see A47 in Figure 2.1) when there is motion in the pedal controls.

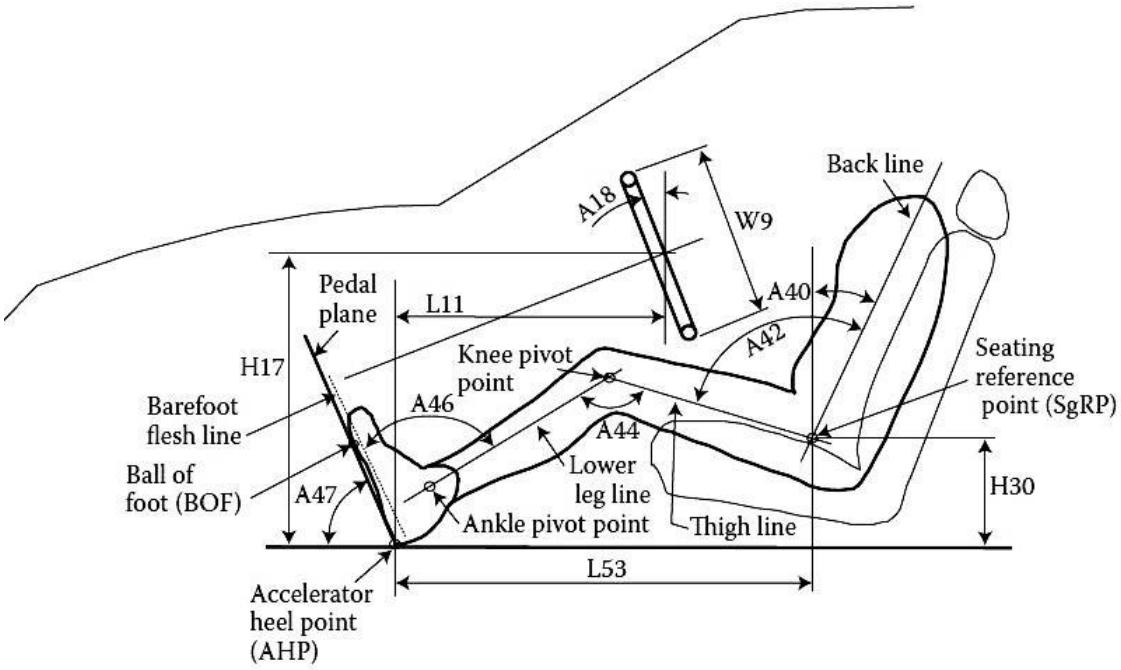

Figure 2.1 Interior package reference points and dimensions (Bhise, 2012).

2.3 DHM in vehicle ergonomics

As Gkikas (2013) mentions, the sector where DHM has been most applied is the automotive industry, with SAE (Society of Automotive Engineers) having had a big influence through standards, committees and conferences.

As previously discussed, the software that is to be feature-wise analysed most thoroughly in this work are IMMA and Jack.

2.3.1 IMMA's current capabilities that influence the high-level language

In order to be able to build a suitable and successful language for IMMA, it is crucial to understand well enough IMMA's current features that will have some impact in that language design that could be identified after several testing. When considered opportune, comparisons with other software may be pointed.

1. TCPs, Joint control, constraints and inverse kinematics

In IMMA joints are controlled by TCPs or Tool Centre Points, being these positioned in each articulation. TCPs are both translation and rotation constraint-wise configurable and for each joint TCP there are also predefined constraints to adjust each articulation's angles with sliders, one axis at a time using higher usability comprising terminology (in/out, twist…).

Joints can also be translated and rotated just by dragging and/or orienting their TCPs manually in the scene window so that the whole body will adapt to a posture that fulfils both all the TCP constraints (using inverse kinematics) and balance and ergonomic posture optimization algorithms (explained later). So for instance, if we wanted to locate the hand in a certain placement and orientation and want this inverse kinematics acting only in the arms joints, we would need to fully lock the rest of the body and then move the wrist's TCP around.

2. Initial posture, balance and posture prediction

Most current initial postures in IMMA have a couple or three TCPs active and constrained by default. In other software like Ramsis, initial postures have more impact in the predictions afterwards made than in IMMA, meaning that when a posture is chosen in Ramsis, all constrained motion created after will have the effect of some certain criteria related to that specific initial posture (truck seating, for instance) when it comes to predict new postures derived from user defined constraints.

IMMA works differently instead: the posture prediction criteria do not belong to initial predefined postures. Thus, once an initial posture is chosen, all the TCP constraints explained in point one are going to work together with always the same posture prediction criteria regardless of the initial posture, that encompasses two main foundations:

a) *The balance criteria*: not only makes sure the manikin is in equilibrium throughout all frames of the motion, but it also provides the most solid position if new external forces came into the scene.
b) *The comfort criteria*: among the usual infinite possibilities to fulfil the all the constraints as a result of commands or manually generated motions, this criteria will attempt to come up with a postural solution for each single motion frame that is most ergonomic or comfortable. This includes criteria like joint angle strategies (covered in *WP2*).

Thus, posture prediction calculates postures for a series of static frames to get a statically solvable and comfortable posture all along the motion that is created. This must not be mixed up with kinematics (which are intended to be implemented in the future), since in the present version there is no dynamic inertia considered in the equations beyond calculations. However,

the current system allows estimating and evaluating time spent in potentially unwanted postures along the way from posture A to posture B.

3. Grip points, support points and seating points

The grasping function has seen to have four main concrete functions:

a) Create wrist's TCP position and orientation entities in respect to an object to be accessible for any calculation at any time.
b) Allow external forces for calculations (feet TCPs also allow these).
c) Help to locate wrists TCP properly in respect to the object by configuring the grasp shape of the fingers, even if fingers don't take part in force calculations.
d) Obtain good quality animation and visual output regarding grasping.

When it comes to support points, they aim to match TPCs similarly to grasping points, but to objects that are supposed to act as static supports rather than be moved by the manikin, so they also require for a force supporting TCP, i.e., hands or feet.

Seat points seem to add modifications to the general criteria after which the manikin is behaved. However, as manikin-actions for the current project will be designed for seating postures mainly, this distinction is omitted.

4. Object paths, anchor frames and reference points

IPS (Industrial Path Simulations) will be merged with IMMA in the future. For this reason, in the current software, the path generation and anchor frame system (reference systems) is not expected to be improved. So in the present, simple paths are generated for objects: from point A with orientation A to point B with orientation B.

In this path generation, anchor frames, which could be seen as the single reference system of an object, would determine the rotation reference. For this reason, in a hinge mechanism (the most common in vehicles interaction elements) it makes it much easier to place the anchor frame aligned with the hinge edge. Likewise, in a ball and socket joint (like in the gearshift) the anchor frame would be place preferably in the centre of the rotating ball. Thus, object articulation is not fully user friendly in the present version.

Reference points can be used to move objects to, manually or via language instructions. These are points created for an object in a relative position in respect to another object. Therefore, at least two objects must be loaded in the scene to be able to create reference points.

5. Motion, timing and collision avoidance

As explained before, a sort of static based motion is generated. IMMA divides actions in frames and sets of frames (segments). The time that each segment takes is calculated by the software and it is also user modifiable.

In addition to TCP constraints balance equations and comfort criteria, there is a checkable box called “collision avoidance”. This criteria makes sure that the manikin will move without colliding itself or the objects around.

However, and unlike with the manikin avoiding collision with itself, when it comes to manikin-object collisions, the manikin will stop any part of the body that is to collide with any object when the most direct balanced and comfortable way to fulfil constraints requires so. Therefore, a less solid posture (but still balanced and as comfortable as the collision avoidance allows) will be acquired. Nevertheless, this does not mean that the manikin will, for example, surround objects that are in the shortest way of the arm when it has to grasp an object, but it would stop before colliding with them. In other words, the manikin will stop the parts of the body that collide throughout the motion and try to reach whatever it was ordered to reach with the remaining parts, but does not still have the ability to automatically create longer paths for limbs that will go around objects, it must be guided breaking down the action into smaller steps, if this happened.

6. Visibility and staring at objects

Visibility features in IMMA are currently quite limited in respect to other specialized software and some DHM tools. There is the option to have the manikin’s viewpoint (vision window), show eye cone (ambinocular vision only), and staring at a point.

7. Manikin families

Manikin families allow having the same constraints for a batch of manikins. So an operation or a manual TCP drag can be carried out simultaneously for all these manikins. If any of those couldn’t fulfil the constraints (reach a grasp, not collide, etc.), they would independently stop without affecting the other manikins in the family. This is very useful to optimize operation setting and avoid repetition, as well as obtaining repeatable results, avoid user errors and identify meaningful cases.

8. Current language’s structure

The current language in IMMA works with operations and instructions. There is a ‘Language Operation Editor’ and inside this, in a separated window, the

'Language Instruction Viewer'. In the first, instructions can be managed to create operations (mainly created and put in order). In the second, instructions itself are created through available manikin-tasks comprising different available user-generated data. In principle, this structure is not aimed to be changed, although the possibilities each of these offer, are of course to be redesigned and enhanced by the design approaches.

2.3.2 Observations and features from JACK 8

As previously mentioned Jack DHM software was tested (aided by included user guide and tutorials) especially due to its high usability interface and TSB and OPT functions. Considerations of interesting features are described below.

General

There are several different entities that can be snapped when moving an object. This is very interesting for IMMA-Virtual Driver as long as it could be implemented in order to be integrated in the instruction language to speed up the workflow. Among these, *sites* (as called in Jack, they can be understood as reference systems or tool center points as currently in IMMA), nodes, edges and faces, are the most interesting.

When the user wants to accurately match a specific point of an object (e.g., H-point in a manikin) place- and orientation-wise with an entity of another object (e.g., H-point in the car model) the site snapping seems the most suitable.

On the other hand, when hands or feet are wanted to be positioned specifically laying on the pedals or grasping the wheel respectively, snapping geometries faces together is a fast way of positioning these limbs in a quite accurate way.

Occupant Packaging Toolkit

This Jack's add-on tool has a quite complete set of functions that facilitate placing the H-point in a vehicle design according to different SAE standard measurements that can be quite easily measured with measuring functions available in the regular scene window workspace.

Once all this data is entered, SgRP point, eyellipses (ellipsoids for the representation of the eye location distribution) and different reach surfaces (surfaces usually used to visualize the reachability of a manikin under certain posture and constraints) can be displayed.

There is also a posture prediction tool founded on UMTRI's research published in SAE. Being the input the measurements of the car taken previously and

choosing a car model of the list for the posture's criteria of the mentioned research, a posture is generated; the manikin will be placed holding the wheel with both hands (10/2 clock grips) and laying the right foot on the accelerator.

Task Simulation Builder

The task simulation builder, which would be the equivalent of IMMA's instruction language, has some potentially relevant functions to be considered when designing the new language. Similarities with the general aims of this project can be found in the next extract from the Jack User Manual version 8.2 (p.190), which is included within the documentation of the software by Siemens (2014):

"TSB […] will allow you to create simulations and animations much more quickly than the standard Jack animation system, and the results will be very flexible for use in "what-if" scenarios involving changing environments, varying human models, and even different numbers of people involved in a task. […] Because simulations are defined at a high level, changes to the humans or environment are not only reflected as differences in the details of the motions (such as a different reach location), but in the timing and content of the results: if an object is moved out of reach, TSB will automatically insert an obstacle-avoiding walk to get it. If a small object is replaced with a large object, TSB will switch from a one-handed to a two-handed grasp." Siemens (2014*)*

The first remarkable feature is the *obstacle definition*: it is a function aimed for the walk function. In IMMA there is also collision avoidance for the manikin which actually works for any action, but the objects or segments to be avoided are in the software's criteria so this can add a lot of extra time to calculations. If the instructions itself had some integrated default and/or customizable options of objects to select to be avoided for any collision, calculus may be notoriously more time-efficient.

Another interesting function is *apply force*. Although it is difficult to guess all the criteria behind, the result of this action is that the manikin reacts to an exerted force changing slightly its posture. As industries demand force analyses, a similar function could be interesting for Virtual Driver (in a near future) to get more accuracy in a resultant posture of an exerted force, for example when pushing a pedal or moving.

2.4 High-level language design in DHM

There are several considerations that were taken into account in throughout the whole development regarding high-level language design in the area of DHM. When it comes to the terminology explained below, is not necessarily often used along the next stages. However, understanding the following concepts, which are basically features and properties of this kind of language in the DHM environment, will implicitly clarify some other concepts, terms, elements and reasons why the design concepts were designed in certain way. Most definitions are supported on descriptions given by Raschke, Kuhlmann and Hollick (2005).

- *Actor:* the abstract construct that represents any entity in the scene with a role in the task simulation such as a human worker, a robot or a grasp point on a tool.
- *Actor state*: high-level, composite notion of the current body posture and motion (i.e., sitting, standing…).
- *Action:* an atomic token of body posture or motion that an actor can assume in order to accomplish a task portion. Stand, Reach, Grasp…
- *Expandability*: the ability the language or software provides to allow the user build-up new manikin-tasks (always inside the field, in this case user-vehicle ergonomics) that were not predefined or initially considered in the design of the language/software.
- *Refinement and reuse of actions:* capability of making adjustments in some constraints and/or parameters that take part or have influence in the 'command' and invalidation of no longer appropriate adjustments after making some change in the input (e.g., paths).
- *Scene:* the current scenario involving all elements in the simulation that is usually displayed in a "scene window", like in any CAD regular software.
- *Task*: description of desired change in the state of the scene, "Get", for instance (to Get something more actors may need a state of change, i.e., perform some actions first). In this report this will be called "manikin-task" to avoid confusion with other tasks like software user-tasks.
- *Task solver*: the element that coordinates available high-level actions in order to determine how a task should be solved.

- *Task condition*: the input to a task that creates constraints on that task's execution. A task can respond in its execution to dependencies of actors, other tasks or conditions.

- *Task exception*: any motive why a task cannot be executed. For example, if a human actor needs is told to fulfil a task (get) that requires an additional action (walk), but the actor's state (sitting) is indicating incompatibility; a task exception should be issued to enable the actor leave the over-constraining state (stop seating and stand up).

- *Tracking*: some recording in the background of the software of all past activities that allows avoiding the need for the program to reanalyze the scene all the time for it to have an updated record of the current state of the elements in the scene.

2.5 About a user-centred system design

Different aspects of cognition and user-centred systems were initially considered including Gestalt Laws, Short Term Memory, Long Term Memory, Explicit and Implicit Memory, as well as mnemonic rules among others. However, some of these were difficult to implement for the language design. Nevertheless, there are two aspects that consider the previous aspects that seemed to be eligible to be directly implemented: the wizard-kind of interface (deductive software workflow approach) and multilayer interface design (expandable menus or half-hidden expert functionalities).

Software usability 'wizard' interfaces fulfil learnability and memorability requirements, guiding users through the process of achieving a specific task. However, both approaches (the regular inductive and the wizard-guided) take similar time for expert users in order to fulfil the same task (Ritter, Baxter and Churchill, 2014).

When software systems are to be used by a range of different user expertise levels, multi-layer interface might be the solution, accommodating both experts and novices users in a single interface (Ritter et al., 2014).

2.6 Study visits to collaborating vehicle companies

The outcome of the three initial study visits that was considered meaningful to understand primary and indirect needs affecting the current project is described below. Note that some of these results apply to future improvements rather than direct implementation in the developed concept (considering the current state of the general Virtual Driver and time limitation of the project mainly). Questionnaires sent in advance can be read in the annexes. Visits were held with Volvo Trucks, Scania and Volvo Construction Equipment in respective chronological order. Results will be separated according to each visit since there was always at least one differentiating factor for each group (type of software or kind of vehicle) and results were generally different.

2.6.1 Study visit to Volvo Trucks

A workshop was carried out with Volvo Trucks as a first contact with the industry, featuring three different experts in the field of user ergonomics in trucks. They showed basic workflow for an ergonomic assessment using Delmia Human DHM, and related questions were asked on the go, as different matters came up. Concerning this project, the following observations derived:

- The positioning of the manikin is made manually starting from a seating default posture, where the location of the H-point is defined after taking in to account experimental data about the sinking of bodies in the cushions so that they have a reference on how deep should the body penetrate the rigid seat model.

- Hands and feet are manipulated through inverse kinematics acting only in the corresponding limb, which is very useful when the general posture is not wanted to be changed.

- If the adjusted limbs to wheel and pedals do not fit comfortably enough according to comfort angles checked externally (i.e., out of the software) there is a whole iteration that reaches the first positioning step.

- The analysis just covers a static driving position and few reach checks and visibility aspects are covered in other specific software.

- Up to six Macros are being used in order to patch functionalities that the software does not have, such as skeleton geometry's export, reach areas' export, and shoe model addition. Most of the used macros ultimately aim to allow checking fulfilment of standards and regulations.

- Little simulations are performed (both in depth and quantity) due to lack of time and although their priority is to fulfil regulations, they would

welcome ‘extra’ functions if they are really easy and especially fast, reliable and repeatable to use.

From these it can be concluded that automation of the tasks in different aspects like manikin setting and extraction (or export) of geometries and data is really needed: although they don’t seem to explicitly ask for it, performing analyses so rudimentarily as they do is quite time consuming and hardly repeatable; therefore, automation would considerably improve efficiency in terms of time, accuracy and repeatability. So being the inefficient time consumption overcome, they would have enough time to invest in other analyses and considerations that could only improve the quality and scope of the ergonomic assessment.

Integration and agglutination of different functionalities (geometry exports, field of view testing…) into a single-software is important insofar it saves effort, time and money of licenses.

2.6.2 Study visit to Scania

A second focus group was performed in Scania. In this case two experts explained generally their usage of Ramsis (the DHM software they use), showing what features they use and what results they get, rather than doing an actual usage demonstration. Later, questions that were sent in advance were openly discussed (available in the appendixes).

Software seemed to be used mainly at early stages but also throughout the project either to answer different questions coming from other engineers or their own questions. Their objective for DHM usage is to narrow down options and use it, in general terms, as a comparative tool, meaning that once standards are fulfilled, the aim is to be the best in the market ergonomically speaking, so approaches are compared between themselves and with competitors’. Absolute figures are hardly valuable in this regard.

They also pointed out that when it comes to the expertise requirements, although results are repeatable, the user must have high awareness of what is he or she dealing with in order the results to make sense and be valuable. So at the end of the day, the experts said benefiting from different output coming from the software as listed next:

- Graphics to improve reports and communication with customers.
- 3D Visibility and reachability surfaces exportable to their CAD software.
- Other data like:

- Maximum force an average human can exert, for instance, in different angles of pedal pushing.
- Comparison of postures with preferred postures comparatively (different segments, how far are they from the preferred posture?).

Among the things they don't actually have but they would like the software to provide, the ones that could be relevant for the current project are:

- Dynamic capability, meaning that accelerations affect in forces and motions. This is too ambitious to fulfil during the duration of the current project although the IMMA project is working on it. Therefore, there is currently no enough knowledge about how is that going to be developed in order to be implemented even as a prospective approach.

- Data about forces along time, able to be automatically graphed and exported. They remarked that, except buttons, which don't need special calculations, since their travel is extremely short, most interaction elements where a force must be exerted have circular motion, so entering a radius for each of these elements in order to get circular paths automatically calculated and graphed would do it nice.

- Ability to lock joints with certain angle in the input for posture predictions.

- Dashboard lights' reflections on windows from the drivers' viewpoint.

2.6.3 Study visit to Volvo construction vehicles

The third focus group carried out was held with Volvo Construction Equipment. In this case also, some guideline questions were sent in advance. in order to get the best from the workshop.

In the first place, general information about construction vehicles was shown, involving different machines, requirements and budgets. A little demonstration of the software was made after, and finally unanswered initial questions issued. Their ergonomic assessment is cantered in wheel loaders, excavators and secondarily in articulated haulers (as they are similar to trucks).

They use ISO standard's SIP point as seating reference, which they admit to be old fashioned and less useful than the common SAE standard's H-Point, which they aren't changing to due to budget reasons. This SIP point is referenced to the seat unlike the H-point, which is measured from the AHP.

In the software demonstration, the "Task Editor" in Ramsis turned to be more a constraint editor rather than a manikin-task editor or generator, which is pursued. So in Ramsis body points of the mesh of the manikin are attached to points, curves or planes (preferably projected curves to avoid errors).

They also had to set the case for each manikin (as seen before at Scania) so the manikin family consideration is confirmedly desired.

Regarding different kinds of interaction elements in construction equipment, which may differ from regular controls from cars/trucks, they are listed as follows:

- Steering wheel and driving levers
- Shifters and Joysticks
- Buttons
- Storage compartments, also out of the regular sitting reach zone, that are usually accessed seating (bending forwards)
- Acceleration, break and clutch pedals
- Other pedals to adjust the whole dashboard height or the wheel position
- Tactile screens that require reach & visibility to the same place

When asked about most time consuming task, a very specific task was mentioned. Sometimes, the manikin is wanted to be placed so that it is guaranteed it sees a certain surfaces' area. This is very time and effort consuming in the actual Ramsis, since there is the possibility to check for visibility of a point, but not to set a constraint that would make the manikin see a whole delimited surface area.

2.6.4 Questionnaire to Volvo cars

Due to recent changes in the department a study visit could not be performed with this collaborator. However, a questionnaire was answered, and some additional details to the input described so far could be obtained:

- Apart from obvious tasks like primary driving tasks, adjustment tasks, seat belt fastening, arm rest evaluation, roominess and small compartment reachability are well valued potential actions for the DHM to simulate.

- Evaluations for passengers would be also highly appreciated. Roominess, (knees, head, etc.). Headrest positions. Armrest position and comfort. Seat belt comfort. Reachability. In general: evaluations of "passenger tasks" such as using items (reading, eating/drinking, iPad usage, listening to music…). Actually, they admit not having enough good methods to evaluate passengers through their current software.

3 Product specifications

Considering the level of abstraction of the product (high-level of abstraction language) of an already abstract product (software), the degree of definition of the product specifications described in this chapter will remain accordingly abstract when compared to the average sort of product design. Moreover, quantitative specifications comprising figures, units or similar definition potential are consequently scarce. The specifications described below mainly respond to WP3 initial aims (explained in chapter 1) and the exploration phase results reported so far.

3.1 Generalities

The product definition should in very general terms to three main perceived industries' factors that are all correlated:

- Lack of time (which often equals to budget) to spend in DHM evaluations.
- Optimization and agglutination of different user tasks in DHM.
- User friendliness focusing in novel users (the harder is to learn the software, the more expensive it becomes for companies to switch to it).

3.2 Requirements & wishes

Requirements show need of minimum fulfilment and wishes are features that the more are fulfilled the more successful the product could be considered. Next, requirements, preceded by the letter 'R', and wishes, marked with a 'W', are presented in the categories of content (focused in what features should have) and quality (focused in how those features should be or work).

3.2.1 Content

R: The language must comprise most basic manikin seating location actions:

- Manikin's H-point (Hip point) location
- Manikin's AHP (Accelerator Heel point) location

The language should encompass at least the following manikin actions while the seating criteria are still active:

- **R:** Operation of all driving and control elements, including: steering wheels, gearshifts, shafts, levers, joysticks, and pedals. Essential driving controls should also be possible to be suggested a placement location even before the object is loaded or positioned by the user. The system will need some basic parameters about the object before it is placed.

- **W:** Primary driving related adjustment elements' operation: seat track/height, wheel position, dashboard height, headrest height, seat belt fastening.

- **W:** Other accesses: doors, mirrors, buttons, compartments.

R: There must be some way to synchronize and coordinate various instructions inside an operation (e.g., enable to simultaneously perform a gear shift with clutch and accelerator instructions and control the synchronization of sub-instructions).

R: There must be command(s) for the manikin to stare at objects while doing any other action at the same time, tackling also constraints assuring manikin-visibility of user-defined areas (see last paragraph at chapter 2.6.3).

W: Joint (Tool Centre Point) constraints and collision avoidance principles should be included in the logics of the different commands when suitable, speeding up considerably the workflow:

- Make most wanted non-standard Tool Centre Point constraints' (i.e., locking the shoulder) suitable shortcuts embedded in certain actions or set them as general checkboxes inside the language operation editor.

- Implement manikin (with itself) collision avoidance in located suitable body segments depending on the task (i.e., forearms and hands for turning wheel with hand over hand technique) to ensure actions are performed effectively.

W: Ability to adjust manikin-task's timing also after feedback from calculations:

- Suggesting means to pre-calculate necessary preliminary actions to fulfil the operation (if needed). Customization of the time for each of those subtasks even before the operation is run should be also available.

- Since other adjustment (like the collision-deriving need of a manual limb-motion adjustment) happens outside the language editor in IMMA, once feedback from the run operation is perceived, the language should ideally contemplate (be able to catch) the manually performed adjustments in order to create an updated operation.

3.2.2 Quality

The language design, affecting the Language Operation Editor and Language Instruction Viewer (explained in point 4.4.1) should be planned so that the overall explorability of the software's capabilities improves as much as possible. All the specifications inside this statement are wishes, because the proposed concepts' explorability and affordance are not qualitatively measurable and the way to perceive these remains subjective except a huge and thorough survey was carried out for each design proposal, which is neither realistic nor feasible for this project.

R: The proposed interface should implement at least one multilayer interface, especially when advanced and basic user-tasks can be differentiated.

W: The language's words should suggest all the capabilities that the respective command/sub-command/option/feature will encompass.

W: The different sections throughout the structure of the design of the language should be accompanied by basic interface design descriptions of the language operation editor and language instruction viewer, so this design should intend to show the existence and location of as much as important features, including selected input.

W: Complementary short-term feasible general interface/input suggestions that improve visibility of features and options are desirable.

W: If some tasks take more time to be set (in what concerns to the language), it should be the tasks that are less frequently/commonly used.

W: Minimize the minimum input (i.e., let customization optional but not compulsory) and offer novel/expert alternatives (default instead of manual input) whenever it is possible.

4 Generation & development

In the present chapter the methods and actual development of the concept generation and detail development of concepts will be issued.

4.1 Methodology for generation and development

4.1.1 First language concept

This stage targets the creation of the first language concept approach. To address it, manikin-tasks derived from specifications and knowledge acquired mainly throughout study visits was considered in a first instance. After all tasks are listed, the most central (important) tasks were organized first, according to criteria that would facilitate efficient workflow. In the process, this was seen to be a structure revolving around the names and features of devices (see chapter 4.2 and on, for more information).

Being the building of the initial concept quite a trial and error method, new needs for the software were identified (explained more in detail from chapter 4.2 on) and consequent solutions designed on-the-go, in parallel coordination to the needs and issues that appeared both in the language structuration, action and option naming and additional proposed features.

4.1.2 Focus group

The focus group with experts was designed and carried out in this stage. The main objective was to have expert validation of the concepts so far and ideas for improvement.

As previous study visits showed that experts were focused in very particular present issues which were often out of the scope of this project and didn't meet future demands, the focus group was added a preliminary stage designed so that experts could have more "out of the box" kind of thinking. This was done by setting different case scenarios so that experts activated their creative potential within the area by showing their views and reflections around these case scenarios and common trouble that usually arises around specific situations in cases (the cases are explained in detail in the appendixes).

Then, second stage was designed for this focus group. In this case, a demonstration of the so far attained concept was shown to experts in a case scenario context, showing step by step through a graphical provisional demonstrator how the case would be assessed with the proposed language design and complements. The case consisted in a wheel placing trial, containing the following tasks:

1. Create/load/define necessary objects, manikins and strategies (the first half was irrelevant, and the second in the scope of *WP2*).

2. Place the manikin family in the correct sitting position. This included seating the manikin and setting necessary constraints.

3. Determine an initial position for the wheel, as close as the optimal according to the desired study by attaching it to the driver in a preferred posture.

4. Refine the position and carry out more specific driving actions interacting with other driving elements in order to have more data to compare different approaches. The interaction with those elements includes correctly synchronized operation of clutch and accelerator pedal and gear shifting.

The development of a feasible and suitable approach of a concept was carried out in an iterative prototyping-testing/validating loop with the software developers and with the previously explained focus group. Thus, as the execution of the concepts was mainly centred in trial and error, a constant developing concept was carried out rather than substantially different concepts. Therefore, there is not a clear boundary between the development and the generation. That is why it was considered as a single stage eventually.

4.1.3 Expert validation

Feasibility of the present concept was aided by the software developers' criteria in this stage. They explained their views around a more developed concept that was shown to them after the feedback of the focus group was implemented. Details of issues like the coordination of parallel instructions were addressed in order to get possible solutions that were implemented in the final concept.

4.2 First concept approach

Taking into consideration all the specifications set before, the first concept was shaped. In summary, the characteristic features of it were the following:

- **Classification of instruction commands according to device types**: whenever verbs could be used to describe commands they were used. However, using nouns of general vehicle elements smartly in combination with suitable verbs (see Figure 4.1) would increase the explorability and affordance for new users. In addition, devices require different input, so applying this criteria would ease coherent automation and defaults of input eventually, even if some more straightforward steps (see 'Evaluation') are needed inside the Language Instruction Viewer.

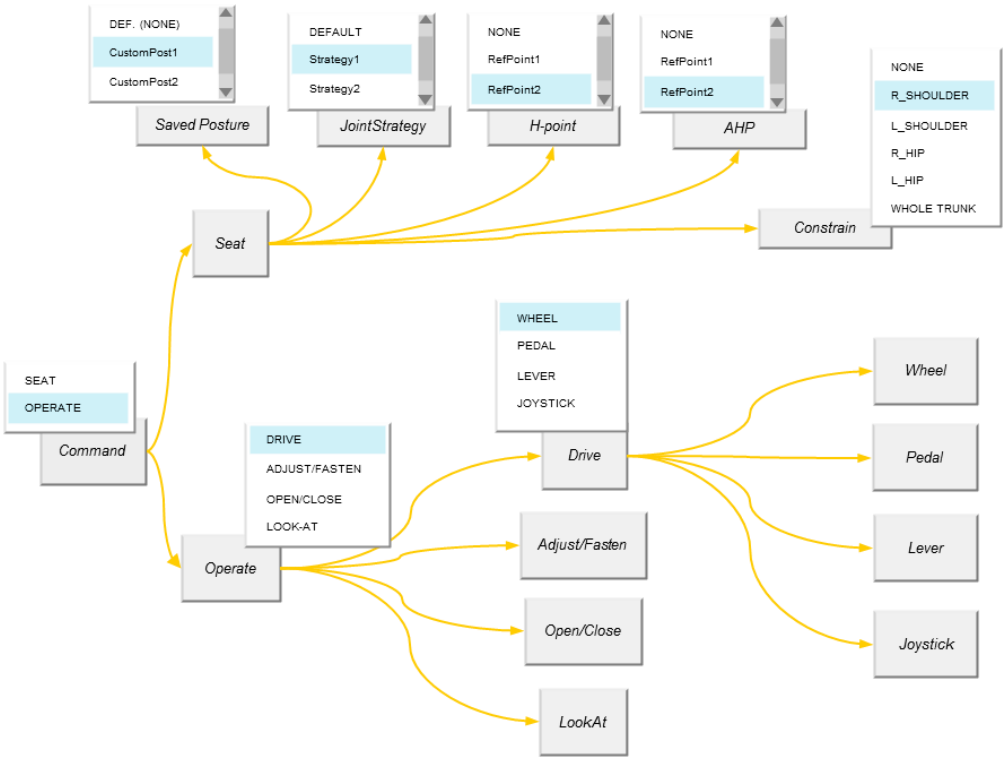

Figure 4.1 General structure of the language in the first concept

- **Design of complementary Object Parameter Editor:** as previously stated in in chapter 1.3, there is high dependency of input modes and toolkits not currently existing in IMMA or in development. For this reason, the need of suggesting an object parameter editor was identified. In this editor, the user would enter parameters in a highly usable way. These will be converted into the objects' anchor fames, as well as adding or creating reference and grip points (among other resources) when necessary, depending on the user's input, type of object and desired customizability. Proposed defaults (explained later) and expected

geometry detection improvements for the near future allow automation (the lightning icons indicating automatic detection in figure 4.2).

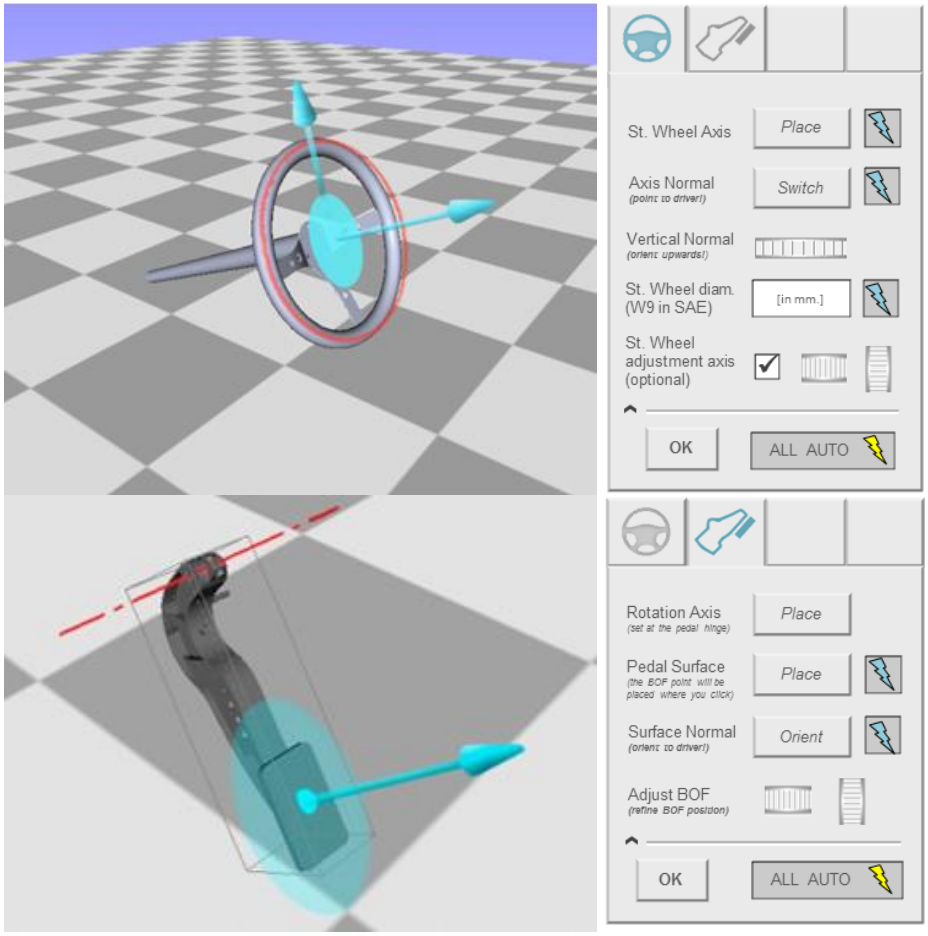

Figure 4.2 Wheel / Pedal Parameter Edition examples (first concept).

- **Analyses of techniques and proposal of defaults:** after having identified this need defaults or at least making some suggestions in order to build a criteria to be followed, some essential techniques regarding steering the wheel were analysed, since this is a principal driving element, which has most different techniques involving wide range of movements. The analysis of these results and derived defaults were kept until the final concept. The full criteria and explanation can be found in annexes (Techniques and Defaults, under appendix 5).

- **Implementation of a Parallel Operation Coordinator:** after considerable testing of IMMA, it was concluded that with the current Language Operation Editor it would be rather difficult to coordinate multiple instructions when the scenario is wanted to be more realistic. In this regard, a Parallel Operation Coordinator was designed, were instructions could be dragged to different layers and then be coordinated and time-modified (see Figure 4.3). Although the general idea has been later confirmed to be useful, some refinements and concretions had to be done later on in order this to be feasible (see following sections).

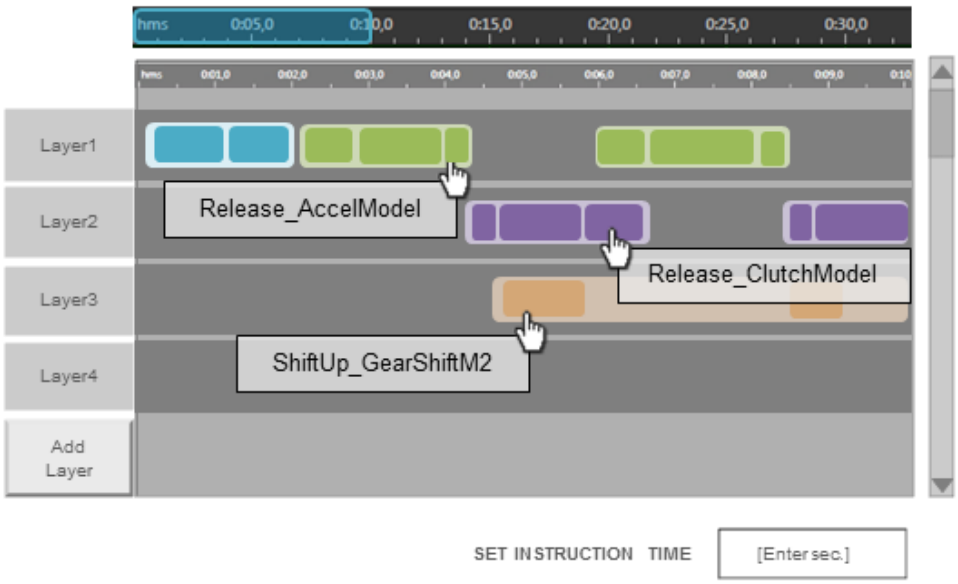

Figure 4.3 First concept of coordination of parallel instructions.

4.3 Focus group

During the concept creation phase the last workshop with industries experts (this time in a form of a focus group) was carried out. Unlike in the previous ones, the experts weren't the conductors of the meeting. Students responsible for *WP2* and *WP3* showed the work done so far so that the experts could input valuable feedback. However, it was seen that in order to have as profitable participation as possible of all the people involved in the workshop some warm up-exercise should be done first. The whole issued subjects can be read in annexes. Although the first par was a warm up exercise, some general issues that can be interesting the current project or follow-ups were summed up. Note that some of them confirm or give value to some of the suggestions realized in the current design, actually.

- The frustration of not knowing what the software is doing (i.e., 'am I doing it wrong? is it a bug?') and the relation of this with user mental models.
- Not getting the same results due to software self-limitations that depend on the current computer circumstances (time limit for calculations, etc.).
- Reaching complicated areas implies many difficulties and the software (current IMMA) doesn't give any feedback of why couldn't done the work.
- Ergonomists; therefore, they often spend more time processing the data that suppliers provide, rather than working with it.

- The lack of software that can easily allow setting a multiple task scenario with more realistic varied and parallel tasks.

From the case scenario based concept demonstration that followed to the warm-up part, valuable feedback was obtained (case scenario explained in annexes). Notice given feedback is categorized in order to be easier understandable and applicable. Apart from the constructive feedback listed below, a positive valuation of the general structure and concept idea was conveyed.

- ***H-point and AHP***: sometimes surfaces for H-point and lines for AHP are wanted rather than points (as suggested so far). This makes no reference point available as fixed. However, those two could be prioritized over all other constraints.

- ***Constraint***: the terminology wasn't clear (this instruction aimed to allow only selected limbs to move. 'Lock' was proposed. 'Lock' it is still considered inaccurate according to the present research so "LimitTo" could be a clearer way to refer to this action that limits all motion to the selected Limb(s).

- ***Wheel – AttatchToManikin***: this action, which would attach the wheel object to the current posture of the manikin, was considered necessary for the great majority of cases so there should be some way to make it by default and specify if you don't want to be executed.

- ***Steer-RETURN:*** should be default (see final concept in annexes).

- ***Pedal angles:*** so far, only pedal angle (from axis) was considered. Pedal arc stroke (calculated at the ball of foot point) is also very common, an should be implemented in the pedal actions as an input option.

- ***Lever (gearshift):*** the name lever is not suitable to englobe gearshift. Besides, it should be as general (rapidly accessible) as wheel and pedals in the language hierarchy due to the fact that is very common action. Regarding the input, sometimes they know the pivot point but sometimes not (they are given it in some engaged gear position). There should be a way to switch between positions. (e.g., 3^{rd} to 5^{th})

- ***Lever (joystick):*** they would call lever the joystick instead, but anyway, the names should be clear enough for different sectors. Lever was checked in the internet in various sites related to construction equipment, and when searches were done lever turned to be a common term to englobe joysticks with other levers. However, the motion principles acting are quite different compared with other levers, so it will be distinguished in a same level from levers in order to facilitate the input.

- ***Instructions and their coordination:*** instructions with sub-instructions (that must happen continuously and unaltered) should be somehow bounded or considered as undividable, atomic, instructions. Make sure that each instruction is allowing to do to other instructions in the while it is run (more detailed explanation and solutions in chapter 4.4).

- ***More about pedals and feet:*** allow BOF line and fixed in pedal instead of point (for accelerator and precise break), BOF point (recommended for clutches and sudden hard breakings), as well as including resting heel points or pivot points (accelerator & break quick switching) for every pedal in instructions. This could be named as “Other HP”.

4.4 Validation from software developers and further advice

The already appreciated general structure was again validated by software developers. Therefore big changes did not have to be done.

However, the concept of coordination of parallel instructions seemed to be undefined enough and lack some important programming core principles that needed some further suggestions in order to make a feasible concept idea.

The issue was that IMMA needs to generate and compute transitions from instructions that use the same body parts, so the coordination cannot be computed unless these dependent instructions are properly noticed to be thus (i.e., dependent) by the user and set in the final desired chain of order in advance to the parallel calculation. So if these instructions could be set in proper order by the user and linked, the software could generate embedded sub-instructions that link other sub-instructions, this way allowing the proposed timeline edition and coordination to some extent, a priori. The implementation of this can be found in the final concept demonstrator in the annexes.

Regarding input methods an object parametrization, software developers already started implementing some ideas on their own, which eventually resulted not to be incompatible with the hereby proposed ones. Actually, their approach was manikin cantered, while the approach presented here is object cantered, meaning that attributes (rotation axes, reference points…) are given to objects, in which, although is not as straightforward, finally there was some agreement that this object oriented workflow could be more intuitive and easier for more crowded or complex vehicles with extraordinary pedals adjustable steering wheels, seat adjustments etc.

Finally, the idea of implementing ranges (pedal and adjustment ranges) was considered important, so it was included in the final concept.

4.5 Final concept

As previously discussed, the process of generation and development was expected to be based on trial and validation of different experts. Thus, and bearing in mind the accepted initial structure, modifications and completions were done in the process, rather than substantial changes. Therefore, the final concept attempts to consider and include all the feedback (and more subtle improvements) received so far, which can be confirmed in detail in annexes.

5 Evaluation

This chapter covers the evaluation of the developed concept, as a response to the "self-evaluation" aim/requirement and since due to the nature of the project there is a lack of actual concept selection, strictly talking.

5.1 Methodology for evaluation

Since finally the concept could not be implemented in IMMA in the time this project was active, a final explanatory demonstrator was created similarly to the provisional one mentioned in the focus group explanation but with higher detail in explanation, updated features and much more complete coverage of the tasks and options to be tackled. This demonstrator is the final language design concept graphically explained with additional functionalities and comments on their performance (fully available in annexes). In other words, it shows generally what can be done with the created language, thus having shaped a solid basis from where to evaluate all the steps to follow in a defined case scenario.

Task Analysis

Thus, the new instruction language performance was compared against the performance of manual operation (this is, without an instruction language) which was performed in this stage. For this purpose, one kind of Task Analysis was performed: a simplified custom variant of the Keystroke Level Model (more about the selection of this particular method in annexes).

As Ritter et al. (2014) explain Task Analysis (TA from now on) provides means to hierarchically describe all tasks made by users considering structure and user required knowledge. Thus, it is possible to carry out estimates about learning and performing times. They also clarify that TA is a very broad method containing a handful of approaches, variants, possible objectives, inputs and outcomes, which have to be thoroughly defined in order to get any meaningful result of it.

Bearing this in mind, the TA will not be used as a tool to set up a new design or carry out substantial changes in the concept to be analyzed, but as a method of valuation of the obtained result and how does it fulfil the initial objectives in a more quantitative way.

"Kirwan and Ainsworth (1992), for example, identify six areas where TA can be applied. […] 1. Person specification, 2. Staffing and job organization, 3. Skills and knowledge acquisition, 4. Allocation of function, 5. Performance assurance, 6. Task and interface design" (Ritter et al., 2014, p.311). Understanding all these areas and possibilities inside each one, it is clear that the last listed, i.e., "task and interface design" is the one being dealt with in the current analysis, of which, among the possible objectives that TA can meet described throughout that category, "to compare different designs" is the desired one. Notice though, that it is not strictly different designs what is going to be compared, but different approaches (manual vs. new language aided) within the same software. In other words, the capability of TA is wanted to clarify how easier and/or faster is one approach.

Feature comparison

To end with, Jack's features (considering TSB and OPT) and IMMA's (considering the new language and complements) were compared in a checklist. The features to be compared were narrowed down to tasks that are central to the quality enhancement of the assessments that a language of this kind can provide in the area of user-vehicle ergonomics.

5.2 Self-evaluation: IMMA manually vs. IMMA with the new language

As it is explained in the 'Methodology', the evaluation phase aims through Task Analysis the current concept and get further feedback, apart from the one provided by experts in the previous iterative phase. The method and criteria on which the analysis is based (KLM) is further explained in annexes. In summary, the following timing criteria were applied to user-steps (see table 4.1):

Category	*Colour code*	*Description / criteria*	*Est. avg. time*
Straightforward (A-TYPE)	Black	Chain-linked steps inside language, obvious steps, little mouse/keyboard action. Medium actions (due to fast recap rather than keyboard/mouse action) that because were very recently repeated, they will most likely be as fast as straightforward.	**1s**
Medium (B-TYPE)	Blue	Interface area/level changing steps, steps that require medium mouse/keyboard action. Fast mental recap of situation to know what to do next. In between actions requiring fast computation time.	**3s**
Slow (C-TYPE)	Green	Non-recurrent Steps that require identification, some reflection or mental recap of situation until next step (or after previous step) or involve considerable scrolling/finding new elements for the first time in a list, or similar. Actions that need medium computation time in between.	**10s**
Halting (D-TYPE)	Orange	Steps that may need external calculations, checking the guide or consulting other matters. Actions requiring in between slow computation time	**30s**

Table 4.1 User-step timing criteria for Task Analysis

In order the two different approaches to have some coherent series of tasks to be compared against; some case scenario had to be designed. The criteria and considerations to determine the case scenario are explained in detail in the annexes, as well as the whole user-instructions (the core Task Analysis) and the colour coded timing that was awarded to each instruction. The current table (Table 4.2) shows the step and estimated time results for the different approaches and parts of the set case scenario.

Task	*Total quantified steps*	*Step type (category)*				*Estimated approx. time*	
		A 1s	B 3s	C 10s	D 30s	Seconds (s)	Min. and sec.
1.1- Adjust the seat horizontally **(new lang.)**	**90**	**33**	**54**	**3**	**0**	**225s**	**3'45"**
1.1- Adjust the seat horizontally **(manual)**	**85**	**19**	**64**	**2**	**0**	**231s**	**3'51"**
1.2-Adjust the steering wheel **(new lang.)**	**127**	**58**	**65**	**4**	**0**	**293s**	**4'53"**
1.2-Adjust the steering wheel **(manual)**	**203**	**77**	**119**	**7**	**0**	**504s**	**8'24''**
2- Complete gear shifting **(new lang.)**	**164**	**84**	**74**	**6**	**0**	**366s**	**6'06"**
2- Complete gear shifting **(manual)**	**449**	**149**	**292**	**2**	**6**	**1405s**	**23'25"**

Table 4.2 Task Analysis step and time sum results.

The first clear conclusion from the previous table is that considering the implemented toolkits that speed the usability of the language especially for non-recurrent users the number of tasks is generally higher in the manual approach.

Notice also that differences in last cases are higher. This is due to the fact that similar actions are repeated (reusability of actions).

When it comes to time, the structure of the language has clear advantages in speed, since the percentage of tasks that are straightforward (A-type) is noticeably higher than in the manual approaches.

All in all, the new language showed higher efficiency in complex tasks regardless the type of user (especially for actions that follow repeated patterns). The timing in all cases was also lower in all language approaches, by few seconds in the less repetitive task, and almost as four times as faster in the most repetitive task (the last listed).

5.3 Feature comparison: IMMA - new language vs. Jack 8

In this section IMMA's and Jack's command languages are compared in order to have also external benchmarking. Therefore, note that this comparison is very specific and will just address key considered vehicle occupant packaging tasks and language or related features that revolve around that area.

The comparison will be done in a checklist table, as it can be noticed below in Table 4.3. The explanation in detail on what is each feature referring to and why is fulfilled or not can be found in annexes. IMMA was considered with the new language and the features that have been expected to be implementable in the near future, i.e., all the features described in the demonstrator (see annexes). As for Jack, Jack 8 version was considered with its Task Simulation Builder and Occupant Packaging Toolkit features.

Bear in mind that the checklist mark can be Y (yes), N (no), or M (only manually). 'Yes' means that the task can be done within the language with little or none manual adjustment. 'No' means that the software can't handle that feature in a plausible user workflow. 'Only manually' means that the feature can only be emulated through considerable manual user setting, performed mainly outside the language environment and with limited results.

Feature	***IMMA*** (with new language and features)	***Jack 8*** (including TSB and OPT toolkits)
Place the manikin in seating position	**Y**	**Y**
Setting and working with object ranges	**Y**	**N**
Perform driving tasks	**Y**	**M**
Element adjustment instructions	**Y**	**M**
Parallel driving task ability	**Y**	**M**
Ingress / egress instruction	**N**	**N**
Service / maintenance tasks	**M**	**M**
Vision constraint	**Y**	**N**
Edition, refinement and update	**Y**	**Y**

Table 4.3 Comparison of language related features of IMMA (new language) and Jack 8.

6 Discussion

This chapter targets to address reflections upon the development of the project, from its definition to the considerations follow up studies should have.

6.1 Definition of the *WP3*

In principle, the aim of this project was to design only the language, meaning that suitable words encompassing proper actions and features in the most efficient and comprising high usability hierarchical structure should be designed.

Nevertheless, throughout the project it was seen that the language cannot request (in its functioning) input methods (like the OPE suggested) that are non-existent in a current version of the software. Moreover, the structure of the language was obviously highly dependent on this factor. Therefore, instead of being limited by this fact, suggestions were made (OPE) accordingly to the language structure that was considered to work best.

Designing defaults was also a key point that initially could have been thought to remain out of the scope of this work. However, it has been seen as a very valuable element towards setting criteria and inspiration for repeatability of results, and also reliability when the actions in real life and software capabilities are properly understood and merged.

When it comes to complex realistic situations, the ability for the instructions to be coordinated was also expected to some extent to be held inside the core of the instructions themselves. Nonetheless, this was finally conceived in the language operation editor environment, making usability simpler.

6.2 Literature study

The literature study was found the most challenging and frustrating part of this project. The main reasons for this to happen were that the project itself is located in a grey area between automotive ergonomics and other very specialized areas expertise, including programming and user centred system cognition and relative areas. Lacking expertise in any of those areas, the first literature approach was unavoidably some kind of wandering.

Although automotive ergonomics' concepts made clear throughout the project since having basic knowledge of ergonomics allows understanding, dealing and

implementing concepts, when it comes to the effective implementation of concepts of programming or cognition, much deeper knowledge would have been needed in order to carry out a literature review that could really revolutionize the course of the design project providing solid evidence behind. In addition to expertise, many approaches (especially regarding cognition) would have needed large, specialized and thoroughly designed expert surveys to have mere verisimilitude.

In summary, the real outcome of the literature review for the project was the familiarization with automotive ergonomics, and the implementation of very basic user-centred solutions for systems, like the multilayer interface.

6.3 Software analysis

The software review was really useful to this work in two senses.

First, as an approach to the vehicle-user oriented ergonomic DHM software in general and to set bases where to design the language around for IMMA, in particular.

Secondly, to get inspiration and contrast different ideas from different workflows and utilities from the software tested, which is mainly Jack with its TSB and OPT toolkits.

Thus, Jack and its toolkits for instance, served both as benchmark to aim further when it comes to future needs for industries and as inspiration to design these features that target the overcome Jack's. To set an instance of this, Jack's timeline inspired the Parallel Operation Editor, which would add substantial functionality.

In the analysis of IMMA provided the essential knowledge to have awareness of what is the ultimate data the software deals with in order to manage it from a higher-level of hierarchy and user friendliness through the language. This can be applied to virtually all the features analysed. For example, TCPs, reference points or grip points are automatically generated through the designed Object Parameter Editor and in different instructions.

6.4 Study visits with collaborators

Meetings with collaborating industries were a very central part of the project due to the importance of identifying and interpreting their needs.

Although the outcome of these may not seem obvious when looking to the final demonstrator, the needs as such that were set from the beginning in form of aims were clarified, and these outcome had notable impact and formed a solid basis for the product specifications, since the project revolves around the meeting of those needs.

Several examples of this could be given:

- Consolidation of AHP and H-point as manikin setting main reference points and details implemented afterwards like ranges and possible freedom of movement of these points (from all visits).
- Definition of the required devices to interact with (from all visits).
- Priority of different manikin-actions to be simulated and therefore to be designed for the language as effective instructions (from all visits).
- Need for a specific field of view operation: visible area constraint, (from Volvo CE visit).

6.5 Design strategy and methods

The whole project was felt very dependent from industries input in the beginning, and actually, this happened. Considering the level of abstraction of the project, especially in initial stages, it would have been extremely hard to look for alternative sources for industry input in the field, and literature provides vague information when it comes to needs for this new area.

A less rigid strategy could have brought enhanced results perhaps. However, the project seemed so centred in the industries needs and collaborators, that to step away from this was implausible in a first instance bearing in mind the initial unacquainted state towards the knowledge that would have provided broader mobility to make early decisions in this regard.

In a hypothetical scenario where the initial focus was not only in familiarizing with those concepts, a more thorough study of future demands and comparisons with other sectors could have been done, thus allowing more out-of-the-box thinking and bringing new ideas.

In spite all this and the little time to develop concepts after workshops, the general method worked as a valid general guidance in a very abstract and difficult-to-define project.

When it comes to the final evaluation, the scenario used and method to evaluate it are both quite limited, as a result of time limitations after general concept validation from experts was possible to be obtained.

6.6 Results from all phases

As previously suggested, results from the study visits (which were expected to be hold in the beginning) came late. For this reason product specifications were not complete enough until the last part of the project in actuality, since other software testing and literature studies just provided ideas but not needs.

With all these difficulties, the outcome of the design was well embraced by different experts, especially throughout the focus group and last discussion with software developers, where several details could be improved.

In the following lines, the results are tested against the specifications and general aims, in order to verify requirements were fulfilled.

6.6.1 Product specifications (aims for the product)

Requirements and most wishes were fulfilled in the design of the final product, even if their nature is not very quantifiable, as explained previously:

- The language included all the required seating location actions and elements (H-point and AHP) and proposed extra functionalities in this regard (inspired in other software), like the 'LockTo' instruction, which would allow inverse kinematics act only in the selected limbs.

- All expected driving tasks were implemented, including all primary controls from cars to construction equipment. What is more, means were developed for each object to be automatized according to its manual operating mechanism characteristics. Primary driving related adjustment elements' instructions were also included.

- One of the most challenging wishes, the coordination of different chronologically overlapping instructions, was also addressed, at least as a starting point conceptual idea of an editable instruction layered timeline, which validated by ergonomist and software development experts. This was based on the linking and pre-calculation of consequent

different manikin-tasks that use same limbs so that motions for these limbs in between these tasks can be generated.

- Regarding visibility, a new instruction mixing ideas from other software and a need presented by experts was suggested.

- Automation of constraints was implemented especially with the automated creation and attachment of reference and grip points throughout the language. Collision avoidance as an instruction in-built element on the other hand, was only seen necessary to tackle the hand over hand steering technique.

- The proposed interface implements the multilayer interface in the two functions where there is clear distinction between basic and advanced functionality: The manual (vs. automatic) input in the suggested Object Parameter Editor, and the Parallel Operation Coordinator functionality that is added to the Language Operation Editor.

- The language's words were validated, as far as they could be shown to experts. The words implemented did not compromise the language structure.

- Interface design descriptions of the language operation editor and language instruction viewer were carried out with explanations of each of the elements (see annexes).

- The structure of the language prioritized the most common tasks higher in the hierarchy.

- Customization and defaults were conceived (which involved design means that can be followed for new defaults), thus satisfying user friendliness, repeatability and flexibility.

6.6.2 General aims and contribution for IMMA

The design covered the top required driving and visibility based manikin tasks that experts pointed out, as well as some other regarding ergonomics of the very adjustment actions.

The feature comparison also had a positive result, showing that IMMA with the new proposals fulfils more software-feature needs that were identified in the vehicle-user ergonomics sector when compared with Jack and its dedicated functions for language instructions and occupant packaging assessment.

Repeatability and reliability of results was found in the setting of criteria and suggestions for defaults and input methods comprising thorough usability, a part of the intrinsic nature of the language, which always suggests one way to do things in comparison to the infinite possibilities of a manual approach.

Some of these statements about the efficiency of the use of the language were tested in a demonstration (see annexes).

In a more general level, the reason of being of this project was fulfilled, meaning that there is not any DHM-ergonomics software that is vehicle-user oriented which includes an ad hoc instruction language. Although it was not compared with the language for assembly, the need of creating new input methods and object parameter edition in order to open to new possibilities demonstrated that the current assembly task oriented language is not enough to fulfil current and future demands. Thus, a new way was undertaken towards the future that Heiner Bubb explains, as quoted in the introductory part of this report.

All in all, IMMA is very flexible and configurable due to the philosophy behind its creation and the agile size of the environment in which is developed. Thus, starting from the suggested approach in this report, and counting on further support of collaborators to set standards, implement requirements on a deeper level and designing a solid and efficient graphic user interface, would allow a highly automatable and configurable software, and easy to use for new users with different backgrounds. After all, the instruction language itself is an interface, since it brings software functionalities to an organized environment where any user familiar with the field should be able to manage.

6.7 General discussion and follow-up ideas

One of the first clear conclusions of this project is the perceived importance of the functionality, tools and defaults underneath the language. A consensus from industries in the definition of different techniques to set defaults and establish a way of better incorporation of objects in the scene could be really interesting.

Furthermore, considering different aspects of the whole concept and development of IMMA that could be experienced in the course of this project, such as its flexibility due to the small and agile context where it is being developed, its solid mathematical-automation oriented foundations, and its collaborative proximity to multiple industries in its development, we could say that IMMA has a great chance to become a sound candidate for the *“completely situation-dependent task”* tackler of the future Heiner Bubb is talking about (see chapter 1).

This could be achieved especially if the current project, which already is oriented to that *situation-dependent* task environment by new features like coordination of parallel instructions, was followed-up towards different elements, areas and needs that can be implemented in new tools and automated functions including the search of consistent defaults, as previously mentioned being important.

Linked to the previous points, and although it is somehow out of the scope of the project's expected outcome, after having experienced all the development in the current research, the physical input ideas mentioned in chapter 1.5.1 are found to be very useful, especially for two aspects that a language like the one designed could hardly afford:

- Manual refinement of particular segments of a motion (see the example of IMMA in the results of the first half of the focus group): the most direct possible mapping to command a Digital Human, is actually a human. Therefore, when struggling complex motions in difficult areas are wanted to be achieved or made more realistic, these physical input tools could simply be in another level.

- Simulate spontaneous motion and lifestyle habits mainly for passengers: following the same reasoning as in the previous point, new horizons could be broadened experimenting with these technologies to meet some of the already confirmed needs (see Questionnaire to Volvo Cars in Appendix 1), like analysing passengers using tablets or eating, testing roominess…

In spite of the fact that Vehicle Equipment was also implemented in the language (including joysticks, levers…) the behaviour and patterns of drivers for this sector are rather unknown and these machines have much more control and adjustment device variety generally speaking. For this reason, the field of Construction Vehicles could be a whole field of study for a new specialized language.

7 Conclusions

This final chapter intends to convey how results met initial aims, in this case following a down to top criteria, going from concrete to general.

The language fulfilled requirements and most wishes:

It included all the required seating location actions and proposed extra functionalities. All expected driving tasks were implemented, including all primary controls from cars to construction equipment and extra adjustment instructions. Objects could be automatized through the designed OPE.

A concept for the coordination of simultaneous instructions (POE) was also addressed and validated by experts. New ideas for visibility instructions were implemented, as well as automation of constraints and collision avoidance.

Multilayer interface was implemented in OPE and POE interface design and the language's words were validated, as shown to experts. Concrete language and interface design descriptions can be seen in the final demonstrator in annexes.

The structure of the language prioritized the most common tasks higher in the hierarchy. Customization and defaults were conceived (involving design means for new defaults), thus satisfying user friendliness, repeatability and flexibility.

Regarding general aims that are not repeated statements when compared to product specifications, they were fulfilled as summarized below:

The feature comparison was carried out, showing that IMMA with the new proposals fulfils more software-feature needs that were identified in the vehicle-user ergonomics sector when compared with Jack and its dedicated functions for language instructions and occupant packaging assessment.

Repeatability and reliability of results was found in the setting of criteria and suggestions for defaults and input methods designed for usability.

Some of these statements about the efficiency of the use of the language were tested in a demonstration with a Task Analysis (see chapter 5 and appendix 3).

In a more general level, the reason of being of this project was fulfilled, meaning that there is not any vehicle-user oriented DHM-ergonomics software with a dedicated instruction language and the current language for assembly tasks was first-hand experienced as not being enough to respond to current and future demands for vehicle task assessment.

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Appendix 1: Questionnaires

Although slightly different questionnaires were sent for each workshop (they evolved through the experience through the workshops), it was considered that a complete list including all questions is suitable to understand the answers and input of each collaborator. Thus, questions are listed below.

- How are postures defined? Is it only with the posture prediction software or are also other types of assessments afterwards? If so, which ones?

- Are the ergonomic evaluations done for the entire body or is it done by parts, depending on the needs?

- What's the step by step of the software usage?

- How is the manikin placed?

- What is expected from the user as a result? Visual analysis or also printed results/charts?

- What are the limitations now? Are there other types of analysis that would be good to evaluate but is not possible?

- How long has the software been in use?

- What are the different actions that you carry out (or would like) the manikin perform throughout your DHM tests (be ambitious if you come up with new suggestions)? Could you explain it with verbs in your own words like if you were actually telling an intelligent robot or a person to perform those actions?

- Is there any action that you test or would find interesting to test especially inside the cockpit apart from driving, checking visibility, operating controls and adjusting elements? (e.g., sleeping, placing quite heavy objects inside)

- Could you list what kinds of control, adjustment and other interaction elements/devices do the different Construction Vehicles have? If it seems they are too many, which is likely considering the variety of Construction Vehicles, could you classify these elements in terms of form of actioning mechanism and placing (i.e., lever, kind of button, wheel, joystick and so forth for mechanism and hand-operated/foot-operated/other criteria that you find interesting for placing)

- If you were to change from your current DHM to other software, what kind of issues do you think could be more problematic when it comes to adapt to the new software (for the user)? What features would you like to preserve from the software you current DHM software?

- Is there any task inside the DHM workflow that especially takes long and would make real difference to speed it up? You can also consider iterations or repetitive try & error processes that could be optimized, automated, etc. when you are thinking about this.

Appendix 2: Focus group

Even though the results of the second part of the focus group are properly summarized in the main report, the first part (less relevant for the results of the project) was not described. Thus, it is discussed more in detail in the current section.

Thus, the first half of the workshop was dedicated to these exercises, where the experts were encouraged to think about different cases, carry out rapid reflections and share and comment on other's ideas, in order to activate the creative flow and set a proper environment to get varied and more inspired feedback when the work was shown eventually. This stage could be considered as a structured discussion where all the steps were time controlled and moderated.

In this first stage, the following exercises were outlined:

1- Best/worst case scenario:

1.1 Please describe briefly (written) and consider the different steps of 2 assessments you worked on that involve DHM. The first should be one that you perceived as especially smooth and/or more successful than initially expected and the other particularly troublesome, confusing, frustrating and/or with an initial result worse than expected.

1.2 Could you identify and write down the critical steps or elements that made each work become as described before (i.e., surprisingly smooth or frustrating)?

1.3 You can now share your reflections and comment on others'.

2- New case scenario

2.1. Think of a new possible assessment case of your very particular area of expertise that involves both DHM and a very new design of some vehicle part. Try to describe it briefly and clearly.

2.2. In other piece of paper: what output would you expect for this analysis in general? What input would you need from the suppliers and in general to do it? Imagine you were in control of the entire project and

wanted a high quality ergonomic assessment. What analysis would you add that you don't do normally?

2.3 Keep your answers and pass your case to the expert at your right hand and answer those questions in point 2.2 for the new case you are given.

2.4 You can now share your reflections and comment on others'.

Although it was a warm up exercise, some interesting output can be summarized:

- The frustration of not knowing what the software is doing (i.e., 'am I doing it wrong?, is it a bug?) and the relation of this with user mental models.

- Not getting the same results due to software self-limitations that depend on the current computer circumstances (time limit for calculations, etc.).

- Easiness of RAMSIS to create real editable (geometrically defined) reach surfaces made out of customizable joint chains.

- Saving issues with PLM systems (it says it is saved but then it is not) and with large assemblies that are difficult to work with.

- Easy and free customizability is very important, both at user level or creating macros.

- Reaching complicated areas implies many difficulties and the software (IMMA) doesn't give any feedback of why couldn't done the work.

- The suppliers give data with little previous reflection on what has to be analyzed that have to be processed by the ergonomists; therefore, they often spend more time processing the data than working with it.

- The lack of software that can easily allow setting a multiple task scenario with more realistic varied and parallel tasks.

After this, the second part begun and the concepts (of WP2 and WP3) were applied to a case scenario, which basically was defined as follows: "*A new adjustable steering wheel has been designed and the best location for it wants to be fetched. The H-point and position of the seat is known."* On the other hand, user tasks were described as below:

1. Create, load and define necessary objects, manikins and strategies.

2. Place the manikin family in the correct sitting position.

3. Determine an initial position for the wheel, as close as the optimal according to the desired study (i.e., what percentiles are adjusting to).

4. Refine the position and carry out more specific driving actions interacting with other driving elements (clutch, accelerator and gearshift) in order to have more data to compare different approaches.

Appendix 3: Task Analysis evaluation

Selected TA: a variant of The Keystroke Level Model (KLM)

Among Task analysis (TA), there are two big pillars: Hierarchical Task Analysis (HTA) and Cognitive Task Analysis (CTA). “Performing an HTA can be a time-consuming process involving many choices” (Ritter et al., 2014, p.315). Besides, HTA is often focused on identifying issues related with the hierarchy (or structure) of the system composed by tasks. In this case, a simple analysis that will provide some time estimation to compare two approaches for a same goal.

The Keystroke level model or KLM (considerable as part of a CTA), is “usually applied where there is just one person interacting with a computer-based system” (Ritter et el., 2014). The method suggests decomposing tasks in steps, and the same author says that the total time is simply calculated by making a sum of the time that all steps take. Although this may seem simple and even the method is a rough approach, it describes accurately concrete components like keystrokes, mouse time (FItt’s law), keyboard /mouse homing time and drawing.

Decomposing and measuring like this the case scenario proposed afterwards is considered too far-fetched for the current project limitations, so a similar simplified approach will be carried out, where steps will be valuated according to four categories, timed and explained in Table 4.1 (in the main report). Note that this categorization, although subjectively figured out, is based on first-hand software experience and data showed in the source of the KLM method. In addition, “further time it takes for the user to work out what to do. The KLM does not provide a way of calculating this but Card et al. (1980) suggest…” (Ritter et al, 2014, p.324). This is also considered. Bear in mind, as well, that timing is thought for a non-expert user, yet somehow instructed in the software (has read a guide, performed education sessions or seen tutorials) and is familiar with DHM software and automotive user-ergonomics.

Setting a case scenario for the comparison

Setting a quite complete case scenario is crucial to evaluate the design. In this case, complete means for the case that will encompass the most meaningful elements of what is expected the language to provide when it comes to the current project, including mainly cockpit tasks like seating, adjusting the main driving elements and driving tasks, involving coordination of simultaneous commands.

Not only is the description of the case scenario important but also how to structure it regarding the consequent TA to be performed, at least in this case. This is due to the fact that many tasks are not comparable for the two approaches (manual/language). Some operations are virtually unattainable without the language, so in the evaluation, the different tasks of the case scenario could be split so that the analysis shows more meaningful results when overall figures are concluded.

It is crucial to distinguish between manikin tasks and user tasks. Notice that in table X, tasks/sub-tasks refers to manikin tasks to be commanded or objectives as Ritter et al. (2014) would call using TA terminology. On the other hand user tasks encompassing concrete user-actions will be analyzed later for each approach once the case scenario is set. This are all the “steps” the user has to follow to reach the objective, which making the manikin perform a certain task.

Preliminary assumptions and considerations

There are previous steps to the tasks the language can tackle like loading and naming of models (objects), creation or loading and selection of joint strategies and creation or loading of necessary manikin or manikin families. These steps are obviated from the analysis since they don’t provide any contribution.

The seating of the manikin (i.e., initial posture and constraints) will be also obviated. In this case the designed language does slightly tackle that step, but as it is just formed by some shortcuts, other more significant tasks will be analyzed.

It has been considered that making a very iterative case scenario where several adjustments made throughout the process would include uncountable variables for each approach, so therefore would be too long and complex to analyze in a clear way, for the time limitations this project has. Therefore, the following described case will gather different manikin actions to test once a certain configuration of a vehicle design.

A truck ergonomic assessment has been chosen for the case since it has more adjustability options than a car. Construction vehicles could have also been chosen, but due to time limitations, it is considered more complex, variable (depending on the construction vehicle type) and less representative of the group of vehicles to be covered as they don’t necessarily have some of the basic controls of cars, trucks, or busses, at least controlled by the same type of driving device.

Case scenario: "DESIGN TEST"

"A new truck concept is to be assessed. The elements that are wanted to be tested include adjustability activators, only the horizontal seat track lever for the new seat and adjustment pedal for the steering wheel. The ergonomic assessment should test different actions that involve the mentioned new elements and some elements whose performance is directly affected by the previous, like driving the current pedals and gearshift. In summary, this includes testing the ergonomics of the action of adjusting the seat and wheel and some driving actions with primary controls." (see Table 3.1).

Tasks/sub-tasks	Some featured actors involved (objects in user- task description will be named as below)	Description
1- Adjustments: get ready to drive		
1.1- Adjust the seat Horizontally	Seat objects • Seat (lower cushion) • Seat Back • Seat Adjustment Lever Manikin • Lever Grip • Toes TCPs constraints Object paths and anchor frames • Seat Adjustment anchor frame • Initial Seat Adjustment Lever path • Seat object horizontal paths	*The manikin will first adjust the seat horizontally from position A to position B, 125 mm backwards in this case. To let the seat slide among the guides, the corresponding lever must be actioned and maintained first and during the whole motion. Legs are the driving force for the seat motion, so toes must be well supported on the floor through all the operation.The seat track angle is assumed to be 0 (horizontal)*
1.2- Adjust the steering wheel	• Column Adjustment Pedal Wheel objects • Steering Wheel • Adjustable Column Manikin • Steering wheel grips (9-3) • Adjustment Pedal Heel Point • Ball Of Foot (Left Toes TCP) Object paths and anchor frames • Steering wheel anchor frame • Adjustable Column anchor frame • Column Adj. Pedal anchor frame • Adjustment pedal path • Wheel objects paths • Reference points for heel, linking objects and Ball of foot in pedal.	*By pressing the correspondent pedal, the manikin will allow the adjustment of the steering wheel column. It is assumed that the driver will find the most comfortable in position in three attempts, so it will perform 3 consecutive motions (involving the release and press of the adjustment pedal each time) which will involve rotation and telescopic adjustment of the column in each motion, all inside the adjustability plane defined by the steering wheel actual adjustability. However, pressing the pedal only will not do it; the wheel is moved being grabbed by the manikin with both hands (9-3 preset grips).*
2- Complete gear shifting		
Accelerating (coordinated) + Clutching (coordinated) + Shifting Up through all gears (coordinated)	• Steering Wheel • Accelerator Pedal • Clutch Pedal • Shifter Manikin • Steering Wheel Grip • Shifter Grip • Accel. Ball Of Foot (Right Toes TCP) • Clutch Ball Of Foot (Left Toes TCP) • Accelerator Heel Point Object paths and anchor frames • Accelerator Pedal anchor frame • Clutch Pedal anchor frame • Shifter anchor frame • Shifter layout paths • Initial Seat Adjustment Lever path • Seat object paths • Reference points for heels and Balls of feet in pedals and shifter layout.	*(FIVE GEARS (CAR-LIKE) 5DRD GEAR LAYOUT ASSSUMED)* *While holding the steering wheel with the left hand, the manikin will start accelerating and then change gears in a coordinated accelerator-clutch-gearshift motion (as it should be in reality) shifting through all gears.*

Table 3.1 Case scenario definition for Task Analysis comparison.

User-Task description considerations

Assumptions and considerations for the user task description:

- ***Followed user-procedure:***
    - The way the goals (accomplish manikin tasks) are going to be tackled is through the most default way possible on the one hand to simplify the variability and on the other hand to reduce steps.
    - When defaults are only available in the language, manual operations should be performed so that a similar result is achieved.
    - When proposed toolkits are used in cases where there is no other comparable option for the manual case like foot attachments for pedals, a figured similar alternative is considered in the regular scene interface. They will be marked with a (*).
- ***Description conventions:*** each line will be called **"USER STEP",** and represents one keyboard/mouse complete action (move+click, click+drag scroll…), reading through a text, identifying a desired element or state, or a combination of any of the keyboard/mouse actions with identification when the identification is sudden after the proper keyboard/mouse action (e.g.: scroll until [-] is found, drag until desired position is attained…). If a whole line is between brackets is just a note; then, it does not count as a user-step.
- ***Omissions:*** "Left click on", being the most common action, is generally omitted in the description (whenever no actions like scroll, read and so on are mentioned in a line it means that is a "click on" action. Sometimes the word click needs to be pointed out, though. When "[-]" (without quotation marks) is written, it means "any" or "the" axis/object name/manikin family name/number that was chosen or defined by the user previously which must be considered for the current action.
- ***Entity Placement assumptions:*** when an object is to be placed with the placement editor or through keyboard+ mouse controls, it is considered

that the user will perform the double action (Drag/rotate [object] in [-] axis until desired position from the current view + Rotate camera for further adjustment/position Check) different amount of times depending on the situation:

  - **(x1)** Once when the object is known to be translated/rotated a specific figure in one axis only
  - **(x3)** An average of thrice when the figure is arbitrary (visual check) but the motion is in one axis only.
  - **(x6)** Six times in average the object position/orientation is already approximated to the target yet the object needs adjustment in several axes
  - **(x12)** Around twelve times when there is a substantial change of position/translation in multiple axes and following refinement of it.

- ***Lack of results in the manual approach:*** as previously suggested, there are actions that involve simultaneous motion of limbs and/or objects that cannot be performed in the manual approach. In those cases, the missing outcome will be pointed out (consider that lack of animation of secondary objects is less important than a lack of manikin motion for calculations, for instance).

Note that the following user-task description is based on the final concept shown in appendix 5 of these annexes.

User-Task description

1- Adjustments: get ready to drive"

1.1 Adjust the seat Horizontally

- NEW LANGUAGE APPROACH

(Required TCPs are already considered to be locked)

Language
Language Operation Editor
New (instruction)
New
Command
Operate
Adjust
Adjustable element → Select Object
Scroll in the list until "Seat" is located
Select Seat
Linked objects → Check "Include actuator mechanism" box
Add linked object ("+" button)
Scroll in the list until "Seat Back" is located
Select "Seat Back"
Include all selected
OK
Adjustment Range
SET
Adjustment Range Creator → Line
Enter length: 185 mm
Locate in scene
{Drag/rotate line in [-] translation axis until desired position from the current view
Rotate camera for further adjustment/position Check} **(x12)**
OK
Create
OK
Adjustment Target
Enter target length position: 125 mm
Actuator mechanism → lever
Select Object
Scroll in the list until "Seat Adjustment Lever" is located
Select "Seat Adjustment Lever"
Object Parameters
DEFAULT (ALL AUTO)
Select lever type → Transversal Grip Lever
Place (Lever Rotation Center)
Click in the object (near an assumed rotation center)
{Drag/rotate point in [-] translation axis until desired position from the current view
Rotate camera for further adjustment/position Check} **(x6)**
OK
OK
Push/Pull lever
Enter angle in deg (10º)
Limb side
LEFT HAND [can be any, actually]
Adjustment coordination
SET
Drag Element bar start (until desired actuator activation lapse after the actuator started)
Drag Element bar end to desired time
Drag Actuator-Pull bar end to match Element bar beginning
Drag Actuator-Maintain bar end to match Element bar end
Create
Close LIV window
New (operation)
Select "AdjustWithLEVER_Seat_00"
Include to operation (click arrow)
Verify
Run

- MANUAL APPROACH

Lacks the simultaneity of all seat elements' motion
Lacks adjustment range for fast future similar operations

(Required TCPs are already considered to be locked)

Scroll in the Scene Tree list until "Seat Adjustment Lever" is located
Expand [+] "Seat Adjustment Lever"
Anchor frame
{Drag/rotate line in [-/R-] translation/rotation axis until desired position from the current view
Rotate camera for further adjustment/position Check**}** **(x12)**
Right click on "Seat Adjustment Lever" in the Scene Tree
New Grip
Click on the Seat Adjustment Lever object at the scene window
Mark "Left"
Choose "Diagonal Power Grip"
Adjust "Percent from open to closed" to a value around 80%
Close
{Drag/rotate the grip in [-/R-] translation/rotation axis until desired position from the current view
Rotate camera for further adjustment/position Check**}** **(x12)**
Right click on grip in the scene window
Grasp
Select "Seat Adjustment Lever" in the Scene Tree or scene window
Placement editor
Mode
Local
Check positive and negative directions sliding [R-] user defined rotation axis as hinge rotation axis.
Enter 10º or -10º according to the previous check
Close
Pose prediction
Right click on "Seat" in object in the Scene Tree or at the scene window
Add reference point
Click on "Lever" in object in the Scene Tree or at the scene window
Right click on "Seat Back" in object in the Scene Tree or at the scene window
Add reference point
Click on "Lever" in object in the Scene Tree or at the scene window
Placement editor → check that Mode is Global
Enter value in [-] axis 125 mm (check lower left corner to determine if positive or negative)
Press Return/Enter key
Close
Pose prediction
Right click on "Seat" in object in the Scene Tree or at the scene window
Move to reference point
Click on the reference point highlighted in black at the scene window
Right click on "Seat Back" in object in the Scene Tree or at the scene window
Move to reference point
Click on the reference point highlighted in black at the scene window

1.2 Adjust the steering wheel

- NEW LANGUAGE APPROACH

(Required TCPs are already considered to be locked)

Language
Language Operation Editor
New (instruction)
New
Command
Operate
Drive

Wheel
Select wheel object
Scroll in the list until “Steering Wheel” is located
Select “Steering Wheel”
Wheel Parameters
DEFAULT (ALL AUTO)
OK
Click on Wheel
Hold
Create
Close LIV window
New (instruction)
New
Command
Operate
Adjust
Adjustable element → Select Object
Scroll in the list until “Steering Wheel” is located
Select “Steering Wheel”
Linked objects → make sure “Include actuator mechanism” box is unchecked
Add linked object (“+” button)
Scroll in the list until “Adjustable column” is located
Select “Adjustable column”
Include all selected
OK
Adjustment Range
SET
Adjustment Range Creator → Sector
Enter length: 250 mm
Enter angle: 40º
Locate in scene
{Drag/rotate line in [-/R-] translation/rotation axis until desired position
Rotate camera for further adjustment/position Check} **(x12)**
OK
Create
OK
Adjustment Target
Enter target length position: 100 mm
Enter target angle position: 8º
Actuator mechanism → Pedal
Select Object
Scroll in the list until “Column Adjustment Pedal” is located
Object Parameters
DEFAULT (ALL AUTO)
Place (Pedal Rotation Center)
Click in the object (near an assumed rotation center)
{Drag/rotate point in [-/R-] translation/rotation axis until desired position
Rotate camera for further adjustment/position Check} **(x6)**
OK
Check if normal is pointing to the driver → if not, Switch
Add Heel Point (“+” button)
Scroll until “AdjPedHeelPt” is located
Select “Adjustment Pedal Heel Point”
OK
PRESS
Enter angle in deg (20º)
Heel support
Adjustment Pedal Heel Point
Limb side
LEFT FOOT
Adjustment coordination
SET

Drag Element bar start (until desired actuator activation gap after the actuator start)
Drag Element bar end to desired time
Drag Actuator-Press bar end to match Element bar beginning
Drag Actuator-Maintain bar end to match Element bar end
Drag Actuator-Release bar end according to desired release time.
Create
Close LIV window
Select “AdjustWithPEDAL_SteeringWheel_00”
Edit (instruction)
Adjustment Target
Enter target length position: 185 mm
Enter target angle position: 20º
Create
Close LIV window
Select “AdjustWithPEDAL_SteeringWheel_01”
Edit (instruction)
Adjustment Target
Enter target length position: 150 mm
Enter target angle position: 16º
Create
Close LIV window
New (operation)
Select “HoldWHEEL_ SteeringWheel_00”
Click + SHFT +click to select “AdjustWithLEVER_Seat_00”, “[…] 02” and “[…] 03”
Include to operation (click arrow)
Verify
Run

- MANUAL APPROACH

Lacks Adjustable Columns motion
Lacks adjustment range for fast future similar operations

(Required TCPs are already considered to be locked)

Scroll in the Scene Tree list until "Steering wheel" is located
Right click on "Steering wheel" in the Scene Tree list
Anchor frame (one axis should be in the rotation hinge of the Adjustable Column
{Drag/rotate line in [-/R-] translation/rotation axis until desired position from the current view
Rotate camera for further adjustment/position Check} **(x12)**
Right click on "Steering wheel" in the Scene Tree list
New Grip (aim is to grab the wheel with the left hand in 9 position)
Click on the Steering Wheel object at the scene window
Mark "Left"
Choose "Diagonal Power Grip"
Adjust "Percent from open to closed" to a value around 80%
Close
{Drag/rotate the grip in [-/R-] translation/rotation axis until any axis aligns with the lever hinge (from current view)
Rotate camera for further adjustment/position Check} **(x12)**
Right click on grip in the scene window
Grasp
Right click on "Steering wheel" in the Scene Tree list
New Grip (aim is to grab the wheel with the right hand in 3 position)
Click on the Steering Wheel object at the scene window
Mark "Right"
Choose "Diagonal Power Grip"
Adjust "Percent from open to closed" to a value around 80%
Close
{Drag/rotate the grip in [-/R-] translation/rotation axis until any axis aligns with the lever hinge (from current view)
Rotate camera for further adjustment/position Check} **(x12)**
Right click on grip in the scene window
Grasp
Scroll in the Scene Tree list until "Column Adjustment Pedal" is located
Select "Column Adjustment Pedal" in the Scene Tree list
Open Object Parameter Editor*
Select Pedal Tab
ALL AUTO.
    Place (Pedal Rotation Center)
        Click in the object (near an assumed rotation center)
        {Drag/rotate point in [-/R-] translation/rotation axis until desired position from the current view
Rotate camera for further adjustment/position Check} **(x6)**
OK
Check if normal is pointing to the driver → if not, Switch
Add Heel Point ("+" button)
Scroll until "AdjPedHeelPt" is located
Select "AdjPedHeelPt"
OK
Scroll in the Scene Tree list until "Family [-]" is located
Expand "Family [-]" in the Scene Tree list
Expand "Manikin [-]" under "Family [-]"
Expand "Target points"
Right click on "Left Toes"
    Attach to BOF point*
    Click on the BOF point in the pedal highlighted in black in the scene window*
Right click on "Left Heel"
    Attach to Heel Point*
    Click on the heel point near the pedal highlighted in black in the scene window*
    (This heel point includes a line for the foot to slide through, generated before in the Object Parameter Editor)
Scroll in the Scene Tree list until "Column Adjustment Pedal" is located
Select "Column Adjustment Pedal" in the Scene Tree list
Placement editor

Mode
Local
Check positive and negative directions sliding [R-] user defined rotation axis as hinge rotation axis.
Enter current + 20º or -20º according to the previous check (the pedal should be pressed down)
Close
Pose prediction
Scroll in the Scene Tree list until “Steering Wheel” is located
Select “Steering Wheel” in the Scene Tree list
Placement editor
Mode
Local
(Considering that the object was placed in the lower angle and telescopic extension from the beginning)
Check positive and negative directions sliding [-] user defined translation axis as telescopic translation axis.
Enter (current displayed + 100 mm) or (current displayed –100 mm) considering the previous check
Check positive and negative directions sliding [R-] user defined rotation axis as hinge rotation axis.
Enter (current displayed angle + 8º) or (current displayed angle – 8º) according to the previous check
Pose prediction
Scroll in the Scene Tree list until “Column Adjustment Pedal” is located
Select “Column Adjustment Pedal” in the Scene Tree list
Placement editor
Mode
Local
Check positive and negative directions sliding [R-] user defined rotation axis as hinge rotation axis
Enter current + 20º or -20º (the pedal should be released)
Close
Pose prediction
Placement editor
Mode
Local
Enter current + 20º or -20º (the pedal should be pressed again)
Close
Pose prediction
Select “Steering Wheel” in the Scene Tree list
Placement editor
Mode
Local
Remember positive/negative directions for [-] user defined translation axis as telescopic translation axis.
Enter (current + 85 mm) or (current – 85mm), accordingly to increase the telescopic extension
Remember positive/negative directions for [R-] user defined rotation axis as hinge rotation axis
Enter (current + 12º) or (current – 12º) accordingly to increase the wheel angle in respect to the vertical
Close
Pose prediction
Scroll in the Scene Tree list until “Column Adjustment Pedal” is located
Select “Column Adjustment Pedal” in the Scene Tree list
Placement editor
Mode
Local
Remember positive/negative directions for [R-] user defined rotation axis as hinge rotation axis
Enter current + 20º or -20º (the pedal should be released)
Close
Pose prediction
Placement editor
Mode
Local
Check positive and negative directions sliding [R-] user defined rotation axis as hinge rotation axis
Enter current +20º or -20º (the pedal should be pressed)
Close
Pose prediction
Select “Steering Wheel” in the Scene Tree list
Placement editor
Mode
Local

Remember positive/negative directions for [-] user defined translation axis as telescopic translation axis.
Enter (current – 30 mm) or (current + 30mm), accordingly to decrease the telescopic extension
Remember positive/negative directions for [R-] user defined rotation axis as hinge rotation axis
Enter (current – 4º) or (current + 4º) accordingly to decrease the wheel angle in respect to the vertical
Select "Column Adjustment Pedal" in the Scene Tree list
Placement editor
Mode
Local
Remember positive/negative directions for [R-] user defined rotation axis as hinge rotation axis
Enter current + 20º or -20º (the pedal should be released)
Close
Pose prediction

2- Complete gear shifting

- NEW LANGUAGE APPROACH

(Required TCPs are already considered to be locked)

Language
Language Operation Editor
New (instruction)
New
Command
Operate
Drive
Wheel
Select wheel object
Scroll in the list until "Steering Wheel" is located
Select "Steering Wheel"
Wheel Parameters
DEFAULT (ALL AUTO)
OK
Click on Wheel
Hold
R_Grip
NONE
Create
Close LIV window
New (instruction)
New
Command
Operate
Drive
Pedal
Foot
RIGHT
Select object
Scroll in the list until "Accelerator" is located
Select "Accelerator"
Pedal Parameters
DEFAULT (ALL AUTO)
Place (Pedal Rotation Center)
Click in the object (near an assumed rotation center)
{Drag/rotate point in [-/R-] translation/rotation axis until desired position
Rotate camera for further adjustment/position Check} **(x6)**
OK
Check if normal is pointing to the driver → if not, Switch

Add Heel Point (“+” button)
Scroll until “AcceleratorHeelPoint” is located
Select “AcceleratorHeelPoint”
OK
Click on Pedal
PRESS
Enter 35 mm stroke
Heel Support
Accelerator Heel Point
Create
Close LIV window
Select “PressPEDAL_Accelerator_00 “instruction
Edit (instruction)
Foot
LEFT
Select object
Scroll in the list until “Clutch” is located
Select “Clutch”
Pedal Parameters
DEFAULT (ALL AUTO)
Place (Pedal Rotation Center)
Click in the object (near an assumed rotation center)
{Drag/rotate point in [-/R-] translation/rotation axis until desired position
Rotate camera for further adjustment/position Check} **(x6)**
OK
Check if normal is pointing to the driver → if not, Switch
Add Heel Point (“+” button)
Scroll until “L_FootRestPoint” is located
Select “L_FootRestPoint”
OK
Change 35 mm to 70 mm in stroke under Press
Heel support
DEFAULT (NONE)
Rest after release
L_FootRestPoint
Create
Close LIV window
New (instruction)
New
Command
Operate
Drive
Shifter
Select object
Scroll in the list until “Shifter” is located
Select “Shifter”
Shifter Parameters
DEFAULT (ALL AUTO)
Place (Shifter Rotation Center)
OK
Shift Gear
DEF. (SHIFT ALL UP AND RETURN TO NEUTRAL)
Create
Close LIV window
New (operation)
Click + SHIFT + click to select all instructions created so far for the current operation
Include to operation (click arrow)
Open Parallel Operation Coordination (gear and double arrow icon)
Select “PressPEDAL_Accelerator_00” instruction in the included instructions in operation box
Copy **(x4)**
Click + SHIFT + click to select all the five Accelerator pressing instruction copies.
Link (the chain button)

Select “PressPEDAL_Clutch_00” instruction in the included instructions in operation box
Copy **(x5)**
Click + SHIFT + click to select all the six Clutch pressing instruction copies.
Link (the chain button)
Pre-calculate (the double gear button)
Select “HoldWHEEL_SteeringWheel_00” and drag it to Layer1 under Parallel Operation Coordination (POC)
Click + SHIFT + click to select all the five Accelerator pressing instruction copies.
Drag all of them to the POC in layer 2
Click + SHIFT + click to select all the six Clutch pressing instruction copies.
Drag to Layer3 in POC
Select “ShiftGearsSHIFTER_Shifter_00” and drag it to Layer4 in POC
Rearrange times and coordination in POC (average of 2 steps per sub-instruction estimated → **x24)**
Run

- MANUAL APPROACH

Lacks proper coordination and timing accuracy unless thorough modification afterwards
Lacks object parameters for shifting and other parameters for future similar analyses

(Required TCPs are already considered to be locked)
(This operation is expected so long when done manually, that a single shifting will be calculated and therefore, **an entire section will be simply multiplied by 4,** assuming that due to recurrency, it takes 4 times the time it takes to do the shifting for the first time to get 5 complete shifts)

Scroll in the Scene Tree list until “Steering wheel” is located
Right click on “Steering wheel” in the Scene Tree list
New Grip (aim is to grab the wheel with the left hand in 9 position)
Click on the Steering Wheel object at the scene window
Mark “Left”
Choose “Diagonal Power Grip”
Adjust “Percent from open to closed” to a value around 80%
Close
{Drag/rotate the grip in [-/R-] translation/rotation axis until any axis aligns with the lever hinge (from current view)
Rotate camera for further adjustment/position Check**}** **(x12)**
Right click on “Steering wheel” in the Scene Tree list
Right click on the grip for the left hand in the wheel at the scene window
Grasp
Scroll in the Scene Tree list until “Accelerator” is located
Select “Accelerator” in the Scene Tree list
Open Object Parameter Editor*
Select Pedal Tab
ALL AUTO.
Place (Pedal Rotation Center)
Click in the object (near an assumed rotation center)
{Drag/rotate point in [-/R-] translation/rotation axis until desired position from the current view
Rotate camera for further adjustment/position Check**}** **(x6)**
OK
Check if normal is pointing to the driver → if not, Switch
Add Heel Point (“+” button)
Scroll until “Accelerator Heel Point” is located
Select “Accelerator Heel Point”
OK
Scroll in the Scene Tree list until “Clutch” is located
Select “Clutch” in the Scene Tree list
Open Object Parameter Editor*
Select Pedal Tab
ALL AUTO.
Place (Pedal Rotation Center)

Click in the object (near an assumed rotation center)
{Drag/rotate point in [-/R-] translation/rotation axis until desired position from the current view
Rotate camera for further adjustment/position Check} **(x6)**
OK
Check if normal is pointing to the driver → if not, Switch
Add Heel Point ("+" button)
Scroll until "L_FootRestPoint" is located
Select "L_FootRestPoint"
OK
Scroll in the Scene Tree list until "Shifter" is located
Select "Shifter" in the Scene Tree list
Open Object Parameter Editor*
Select Shifter Tab
ALL AUTO.
Place (Shifter Rotation Center)
Click in the object (near an assumed rotation center)
{Drag/rotate point in [-/R-] translation/rotation axis until desired position from the current view
Rotate camera for further adjustment/position Check} **(x6)**
OK (Reference points will be generated for shifting layout)
Scroll in the Scene Tree list until "Family [-]" is located
Expand "Family [-]" in the Scene Tree list
Expand "Manikin [-]" under "Family [-]"
Expand "Target points"
Right click on "Left Heel"
Attach to Heel point*
Click on the "L_FootRestPoint" point at the left of the pedal, highlighted in black in the scene window*

(x4 loop starts here, the variable is [next gear reference point])
Right click on "Right Heel"
Attach to Heel point*
Click on the "Accelerator Heel Point" near the accelerator (highlighted in black in the scene window)*
Right click on "Right Toes"
Attach to BOF point*
Click on the "Ball of Foot Point" on the accelerator pedal (highlighted in black in the scene window)*
Scroll in the Scene Tree list until "Accelerator" is located
Select "Accelerator" in the Scene Tree list
Placement editor
Check positive and negative directions sliding [R-] user defined rotation axis as hinge rotation axis
Calculate angle for a 35 mm arch pedal stroke (consider BOF to rotation axis radius)
Enter calculated value in [R-] as positive or negative according to previous check (remember the current)
Close
Pose prediction
Select "Accelerator" in the Scene Tree list
Placement editor
Enter the value appearing last time before edition (the original, remembered)
Close
Right click on "Left Heel"
Release
Right click on "Left Toes"
Attach to BOF point*
Click on the "Ball of Foot Point" on the clutch pedal (highlighted in black in the scene window)*
Pose prediction
Scroll in the Scene Tree list until "Clutch" is located
Select "Clutch" in the Scene Tree list
Placement editor
Check positive and negative directions sliding [R-] user defined rotation axis as hinge rotation axis
Calculate angle for a 70 mm arch pedal stroke (consider BOF to rotation axis radius)
Enter calculated value in [R-] as positive or negative according to previous check (remember the current)
Close
Right click on "Shifter Grip Point" in the scene window
Grasp
Select the Shifter in the scene window (reference points should be visible

Placement editor
{Drag/rotate line in [-/R-] translation/rotation axis until the Shifter's Handle matches the N (neutral) reference point
Rotate camera for further adjustment/position Check**}** **(x12)**
Close
Pose Prediction
Placement editor
{Drag/rotate line in [-/R-] translation/rotation axis until the Shifter's Handle matches the **[next gear]** reference point
Rotate camera for further adjustment/position Check**}** **(x12)**
Scroll in the Scene Tree list until "Clutch" is located
Select "Clutch" in the Scene Tree list
Placement editor
Enter the prior calculated value in [R-] as opposite as before (to go back to the non-pressed clutch state
Close
Scroll in the Scene Tree list until "Accelerator" is located
Select "Accelerator" in the Scene Tree list
Placement editor
Enter previously calculated value in [R-] as positive or negative to return to a non-pressed accelerator state
Close
Pose prediction
Right click on "Left Toes" in the scene tree
Release
Right click on "Left Heel" in the scene tree
Attach to Heel point*
Click on the "L_FootRestPoint" point at the left of the pedal, highlighted in black in the scene window*
Pose Prediction
(x4 loop ends here])

The total sum of steps and estimated according time of these descriptions can be found in the chapter 5.2 in the main report, more precisely in Table 4.2.

Appendix 4: Feature comparison (IMMA/Jack)

Description of features to be compared and reasoning of the given mark (Y-Yes, N-No or M-Only manual) are addressed as follows:

Place the manikin in seating position: use predefined points in manikin and objects (AHP, H-point, Wheel grips) to get a driving initial posture with a possibility of holding the wheel. Both IMMA (**Y**) in the new language and Jack, through OPT (**M**) can do this.

Setting and working with object ranges: while Jack (**N**) does not work with object ranges (except for manikin joints), IMMA (**Y**) in its new version aims to implement this feature that would be available through the language and taking part in the instructions.

Perform driving tasks: while the new language of IMMA (**Y**) is designed to tackle driving tasks (involving all types of driving devices) with specific parameters and considerations for each task, Jack (**M**) is currently addressing static postures, reach and other standard data surfaces and in some case tediously set animations (except they are done through the TSB, of which tasks are not vehicle oriented), therefore being much more limited, inaccurate and with high likeliness to obtain unwanted results unless thorough manipulation and refinement is done.

Element adjustment instructions: this function refers to interaction of adjustable objects and synchronized manikin-tasks to actually adjust those objects.

IMMA (**Y**): has a specific instruction to adjust elements.

JACK (**M**): could attain similar results by operating the activating mechanism via TSB and later on moving the adjusted part accordingly. However, this would take much longer since animations have to be more thoroughly set, and will lack repeatability and criteria in general.

Parallel driving-task ability: different limbs can be used in parallel to perform different manikin-tasks. For example, break with the right foot-leg while reducing a gear with the right hand-arm in the shifter.

IMMA (**Y**): could perform this through the proposed Parallel Operation Editor (see demonstrator in appendix 5).

Jack (**M**): could not attain this result inside the language environment or TSB, since Jack TSB does not work with several limb coordination except for worker tasks, usually involving only hands (Get, Put, Position, Touch, Regrasp and apply force TSB actions) or just automated walk/support as parallel motions, involving legs (Go, Pose, Sit/stand TSB actions). However, this tasks could be limitedly attained through Jack's Animation System Module of which Jack's user-guide points out, *"While Jack offers a powerful (yet easy to use) animation tool, a person using Jack needs to realize that animation is a very time consuming endeavour and patience is required to do involved projects."*

Ingress / egress instruction: although IMMA is developing a tool for this none of the software is yet able to tackle ingress / egress through their corresponding language operation.

Service / maintenance tasks: both IMMA (**M**) and Jack (**M**) are

Vision constraint: there is an instruction in the language or a quick way to constraint the manikin so that it can see (throughout all the time the constraint is on) a defined object or object part.

IMMA (**Y**): the 'LookAt' instruction in the High-level language would allow setting this constraint to be acting in parallel with other actions.

Jack (**N**): different visibility analyses can be performed, with particular detail in the Occupant Packaging Toolkit. However, all these are *a posteriori* checks of a current posture. There is no way that a constraint can be set in relation to a fulfilment of the sight of the manikin in respect to other objects.

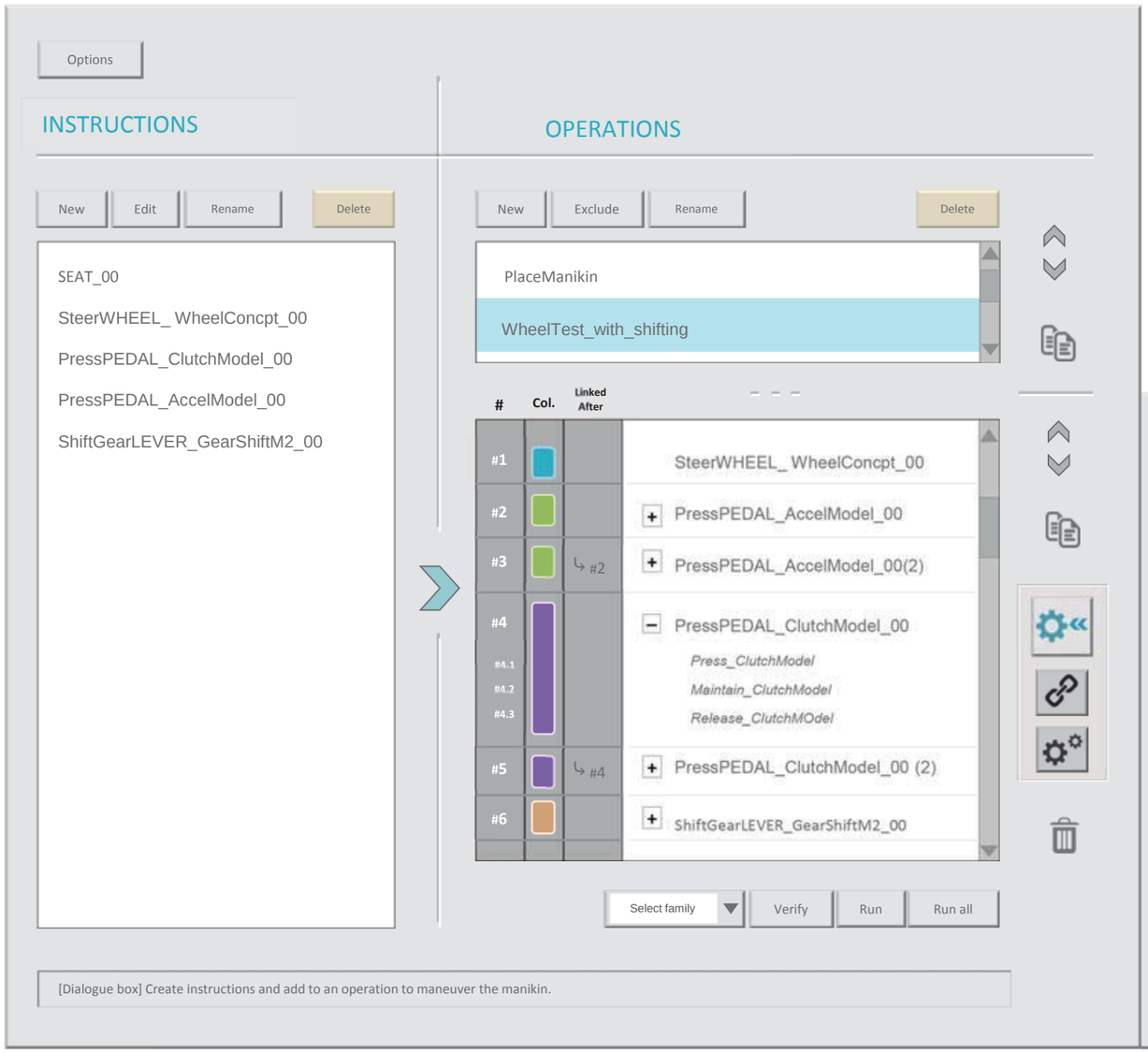
Edition, refinement and update: there is the possibility of further modification and update in the instructions/tasks after the elements in the scene have been modified reasonably (i.e., not exaggeratedly), including, object locations, manikins involved, manikin postures, time duration and chronology of events etc.

IMMA (**Y**): it would be fulfilled supposing the Parallel Operation Editor would work as expected once implemented (look demonstrator in appendix 5 for further details), meaning as well that after pre-calculations, reasonable changes could be made in the scene maintaining the possibility of further edition of the instructions in the language operation editor.

JACK (**Y**): what-if scenarios can be tested in TSB by moving objects, changing manikin sizes, etc. Tasks are also editable manually at any moment (timing of actions, input data and some manual refinement of manikin depending on the kind of instruction).

Appendix 5: Final concept demonstrator

In the following pages the final concept will be shown. Necessary descriptions to understand functions and interface are embedded.



IMMA needs to generate and compute transitions from operations that use the same body limbs, so the coordination of several instructions in parallel to consequent instructions sharing the same limb cannot be computed unless these consequent instructions' dependence is properly noticed by the user and set in advance to the Parallel Operation Coordinator (POC).

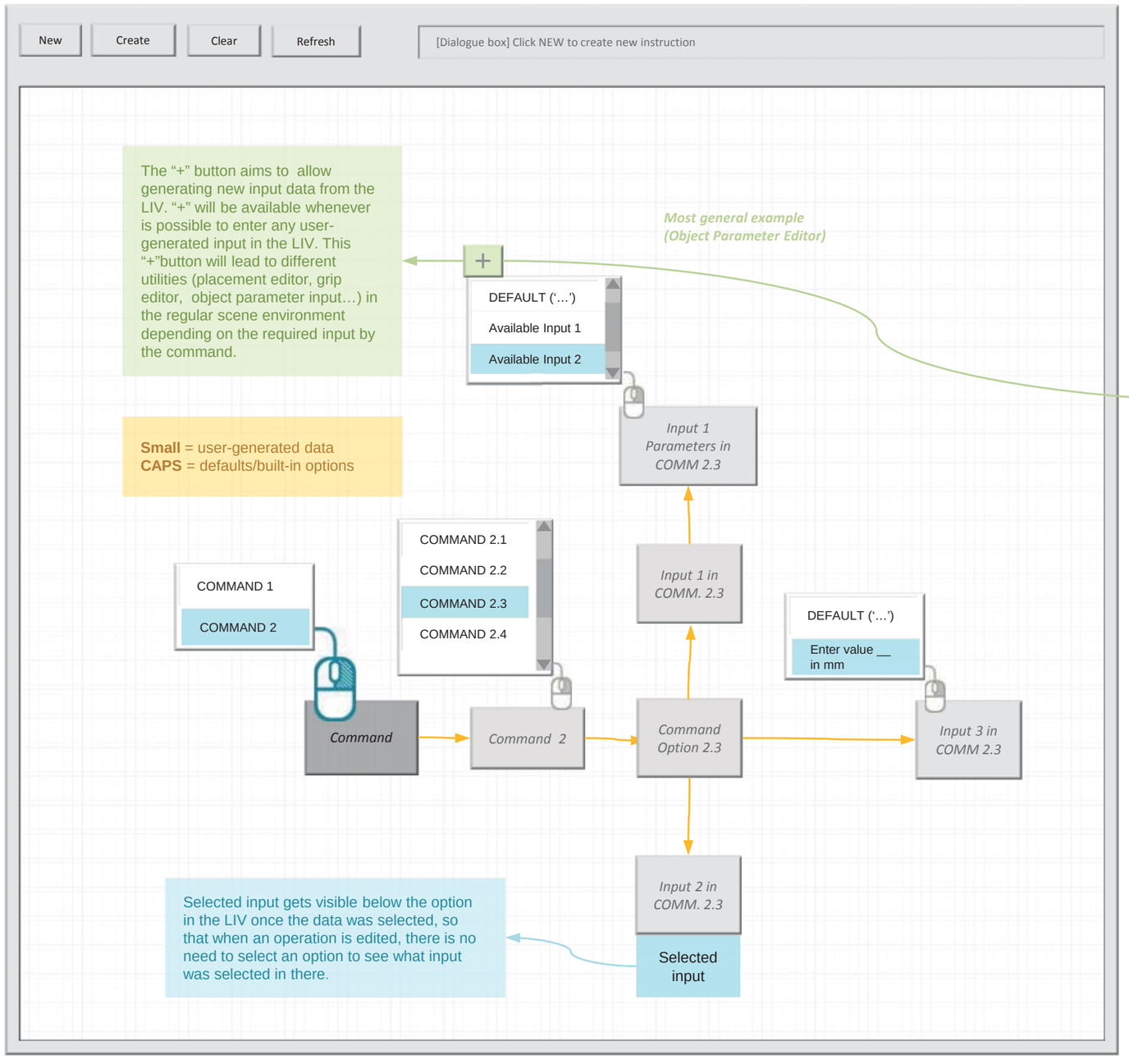
Therefore, the user should link those instructions clicking the chain icon and pre-run them , so that the software could calculate intermediate steps and build them as embedded instructions that link user generated instructions and that way allow timeline edition and coordination. A message warning this would appear over the Parallel Operation Coordinator each time it is opened, with a 'don't show again' checkable exception box.

Sub-instructions inside the same instruction will be automatically linked to prevent parallel actions from interfering.

Notice that once the POC menu is activated, instructions appear now colour labeled and numerated, so that they can be clearly distinguished in the POC and shown which instruction are linked to (if there is any) for pre-calculations (see explanation in the upper text). Not only that, instructions can then be expanded to see what sub-instructions are made of (if there is any), and thus understand and modify instructions timing and chronology in the POC as desired. When instructions are linked, the order remains as in the order of list, so if order wants to be changed, any of the instructions should be selected, then press link again (to unlink them) reorder them with the up/down arrow buttons and finally link the m in order them to be pre-calcuated in the right order.

MULTILAYER INTERFACE

It accommodates both expert and occasional users (Ritter et al., 2014). The POC function is initially hidden, as well as colour labeling, numeration, expandability an linking of instructions in the instructions box under 'operations'. In a first instance then, the controls interconnecting instruction in operations and POC would look disabled like in the figure in the left.


New
Create
Clear
Refresh
[Dialogue box] Click NEW to create new instruction
The “+” button aims to allow generating new input data from the LIV. “+” will be available whenever is possible to enter any user-generated input in the LIV. This “+”button will lead to different utilities (placement editor, grip editor, object parameter input…) in the regular scene environment depending on the required input by the command.
Most general example (Object Parameter Editor)
+
DEFAULT (‘…’)
Available Input 1
Available Input 2
Small = user-generated data
CAPS = defaults/built-in options
Input 1 Parameters in COMM 2.3
COMMAND 2.1
COMMAND 2.2
COMMAND 2.3
COMMAND 2.4
Input 1 in COMM. 2.3
COMMAND 1
COMMAND 2
DEFAULT (‘…’)
Enter value __ in mm
Command
Command 2
Command Option 2.3
Input 3 in COMM 2.3
Input 2 in COMM. 2.3
Selected input
Selected input gets visible below the option in the LIV once the data was selected, so that when an operation is edited, there is no need to select an option to see what input was selected in there.

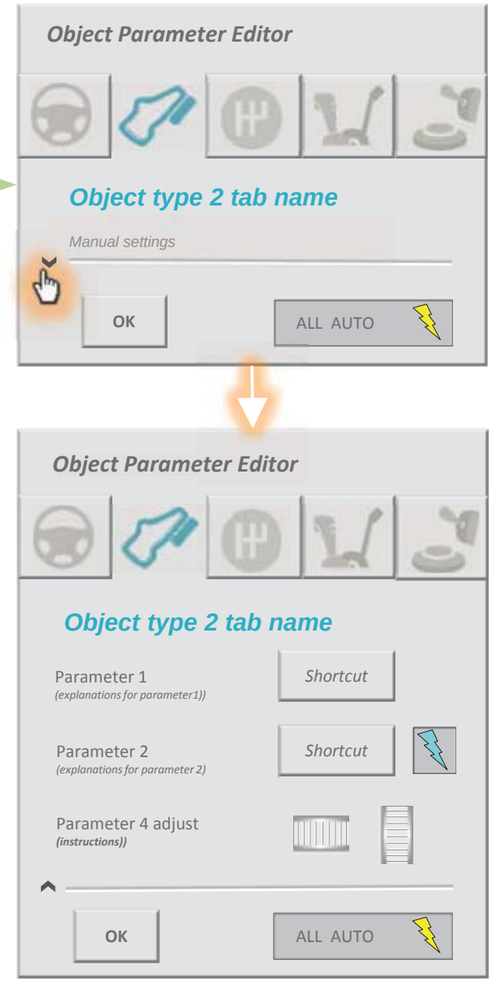
WORDS vs. ICONS

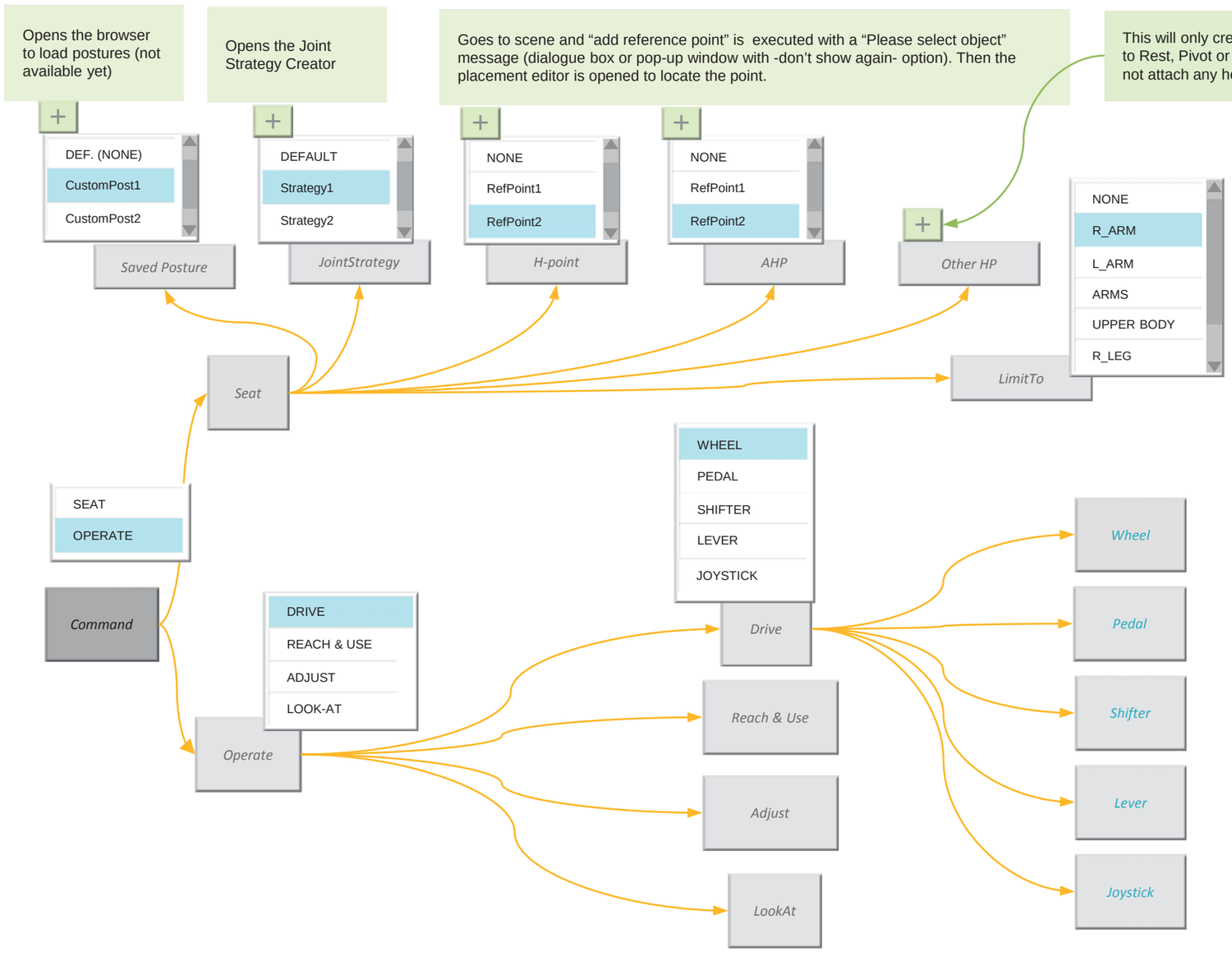
Generally words are used to describe all actions/sub-actions/settings instead of icons as encouraged by Ritter et al. (2014), who explain that unlike icons words are easier retrievable from memory, less likely to be interpreted wrong, among other reasons.

In the ‘Object Parameter Editor’ input multitask interface (generic example) shown below, icons were used for tabs, since they will represent for very different elements that are to be configured geometrically, so the user should know what kind of element is dealing with. Besides, the text in the options mentions it.

MULTILAYER INTERFACE

It accommodates both expert and occasional users (Ritter et al., 2014). Advanced functionality is initially hidden.





All the criteria and constraints applied to the manikin by a SEAT operation will keep active until another SEAT operation is run.

If any of those is attempted to be changed manually outside the language, a warning message should pop-up saying something like:

"***You are about to modify one or several parameters defined by a SEAT operation.*** *Notice that if you alter any the rest will be active but you will no longer be able to rely on the parameters shown in the SEAT instruction to keep track of the active ones."*

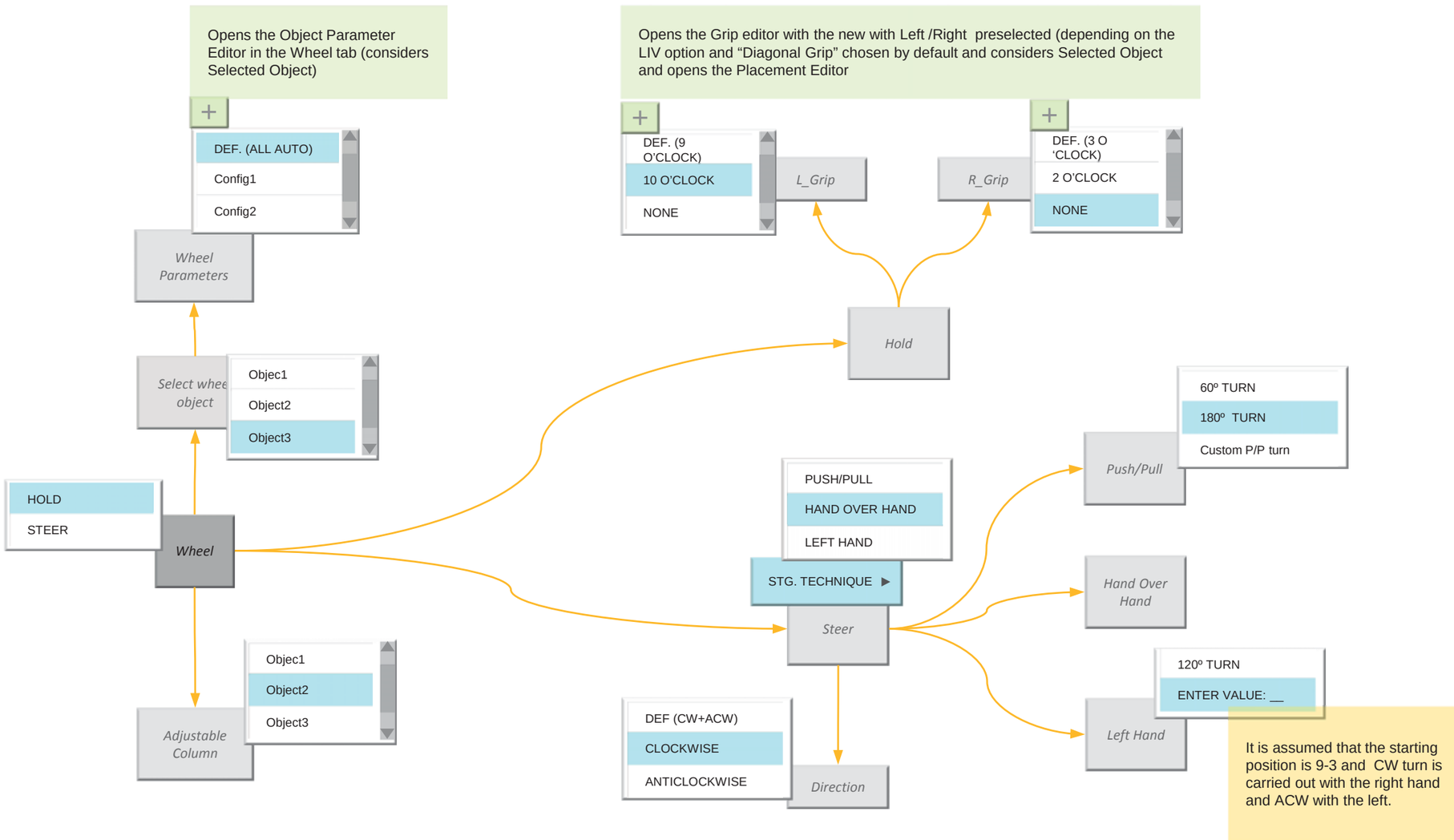
Def. instruction name: SEAT_##

Opens the Object Parameter Editor in the Wheel tab (considers Selected Object)

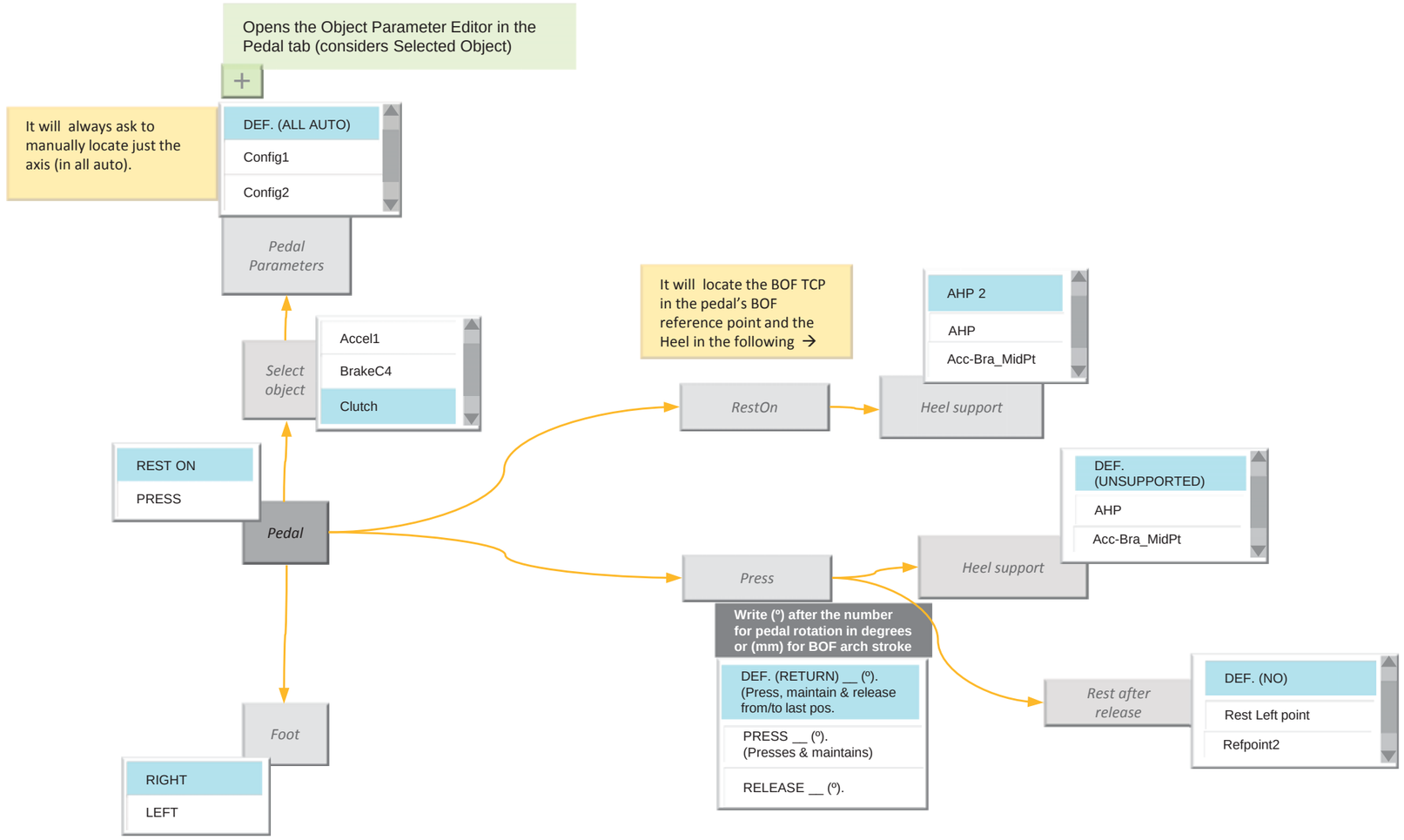
Opens the Grip editor with the new with Left /Right preselected (depending on the LIV option and “Diagonal Grip” chosen by default and considers Selected Object and opens the Placement Editor

Default instruction. name: HoldWHEEL_CADfileName_##

Default instruction. name: SteerWHEEL_CADfileName_##

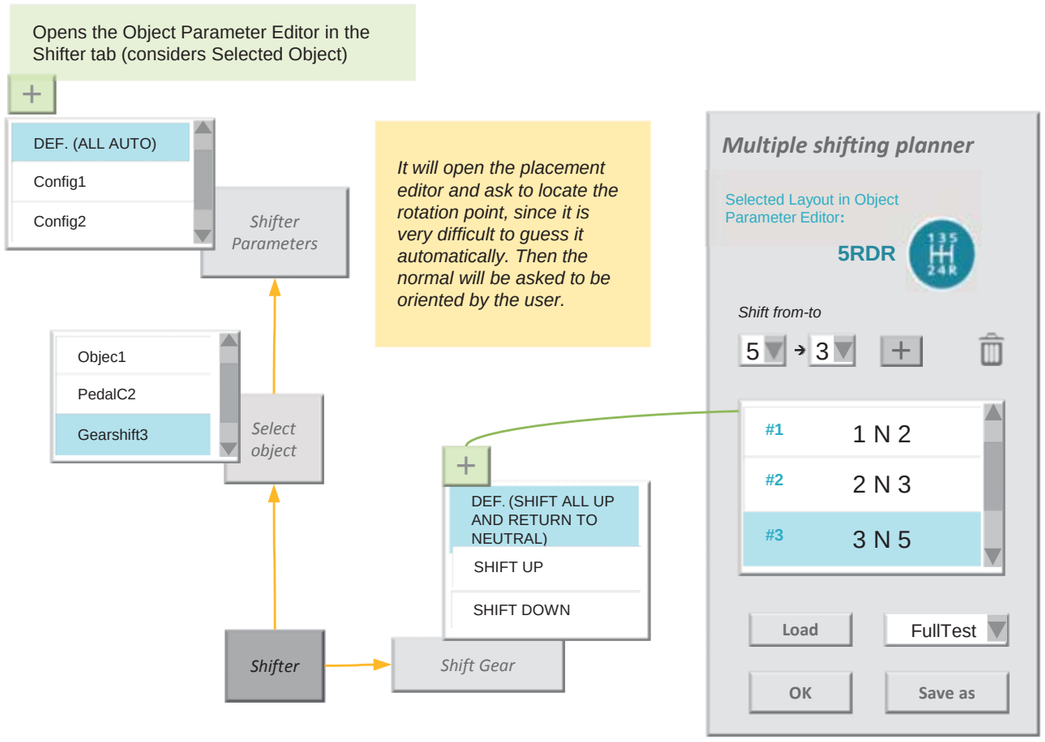


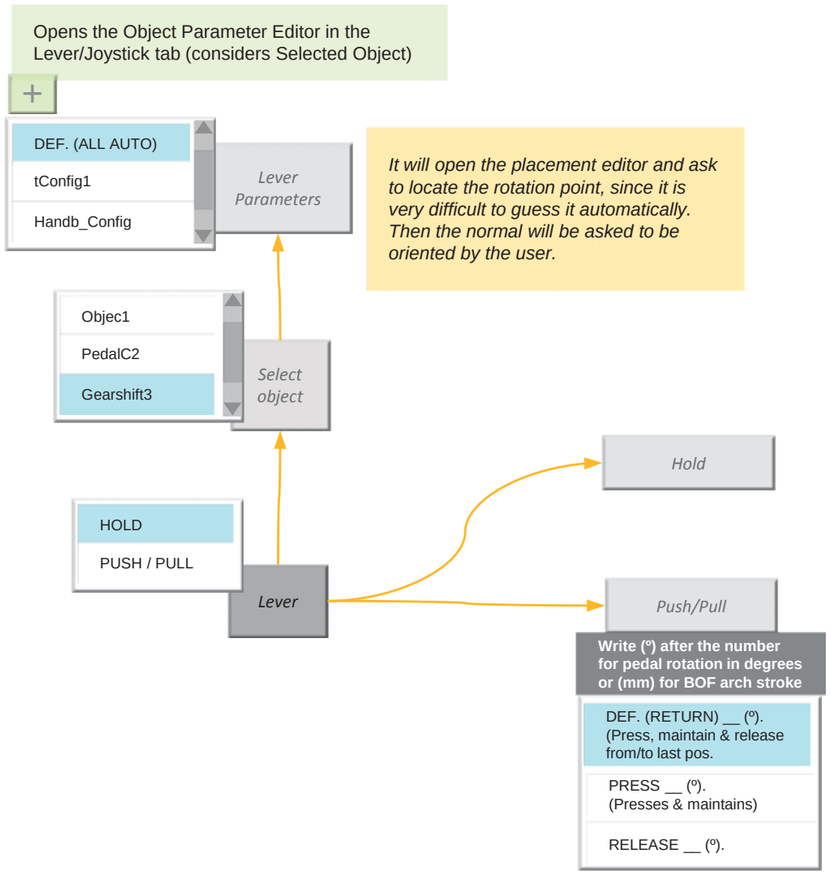
It is assumed that the starting position is 9-3 and CW turn is carried out with the right hand and ACW with the left.

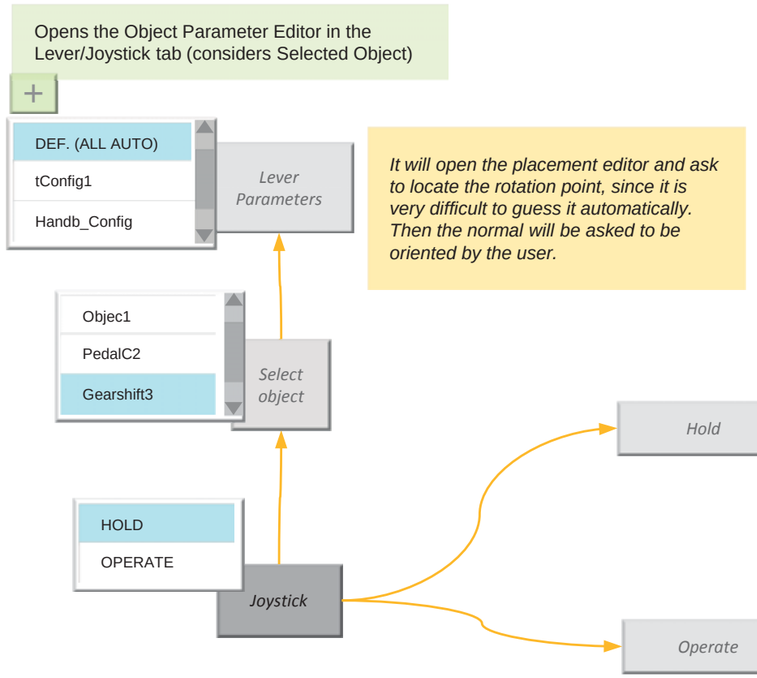


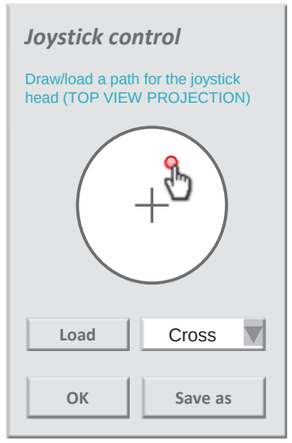
Default instruction. name: RestOnPEDAL_CADfileName_##

Default instruction. name: PressPEDAL_CADfileName_##

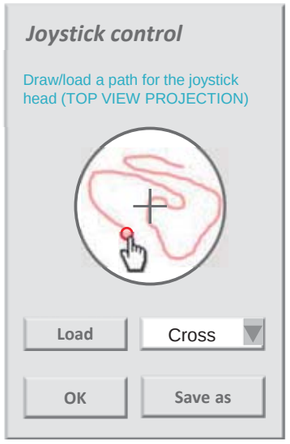

Opens the Object Parameter Editor in the Shifter tab (considers Selected Object)
DEF. (ALL AUTO)
Config1
Config2
Shifter Parameters
It will open the placement editor and ask to locate the rotation point, since it is very difficult to guess it automatically. Then the normal will be asked to be oriented by the user.
Objec1
PedalC2
Gearshift3
Select object
Shifter
DEF. (SHIFT ALL UP AND RETURN TO NEUTRAL)
SHIFT UP
SHIFT DOWN
Shift Gear
Multiple shifting planner
Selected Layout in Object Parameter Editor:
5RDR
Shift from-to
5
3
#1 1 N 2
#2 2 N 3
#3 3 N 5
Load
FullTest
OK
Save as


Opens the Object Parameter Editor in the Lever/Joystick tab (considers Selected Object)
DEF. (ALL AUTO)
tConfig1
Handb_Config
Lever Parameters
It will open the placement editor and ask to locate the rotation point, since it is very difficult to guess it automatically. Then the normal will be asked to be oriented by the user.
Objec1
PedalC2
Gearshift3
Select object
HOLD
PUSH / PULL
Lever
Hold
Push/Pull
Write (º) after the number for pedal rotation in degrees or (mm) for BOF arch stroke
DEF. (RETURN) __ (º). (Press, maintain & release from/to last pos.
PRESS __ (º). (Presses & maintains)
RELEASE __ (º).


Opens the Object Parameter Editor in the Lever/Joystick tab (considers Selected Object)
DEF. (ALL AUTO)
tConfig1
Handb_Config
Lever Parameters
It will open the placement editor and ask to locate the rotation point, since it is very difficult to guess it automatically. Then the normal will be asked to be oriented by the user.
Objec1
PedalC2
Gearshift3
Select object
HOLD
OPERATE
Joystick
Hold
Operate
DEF. (2 circles CW+ACW with max. inclination of joystick)



Default instruction. name: HoldJOYSTICK_CADfileName_##

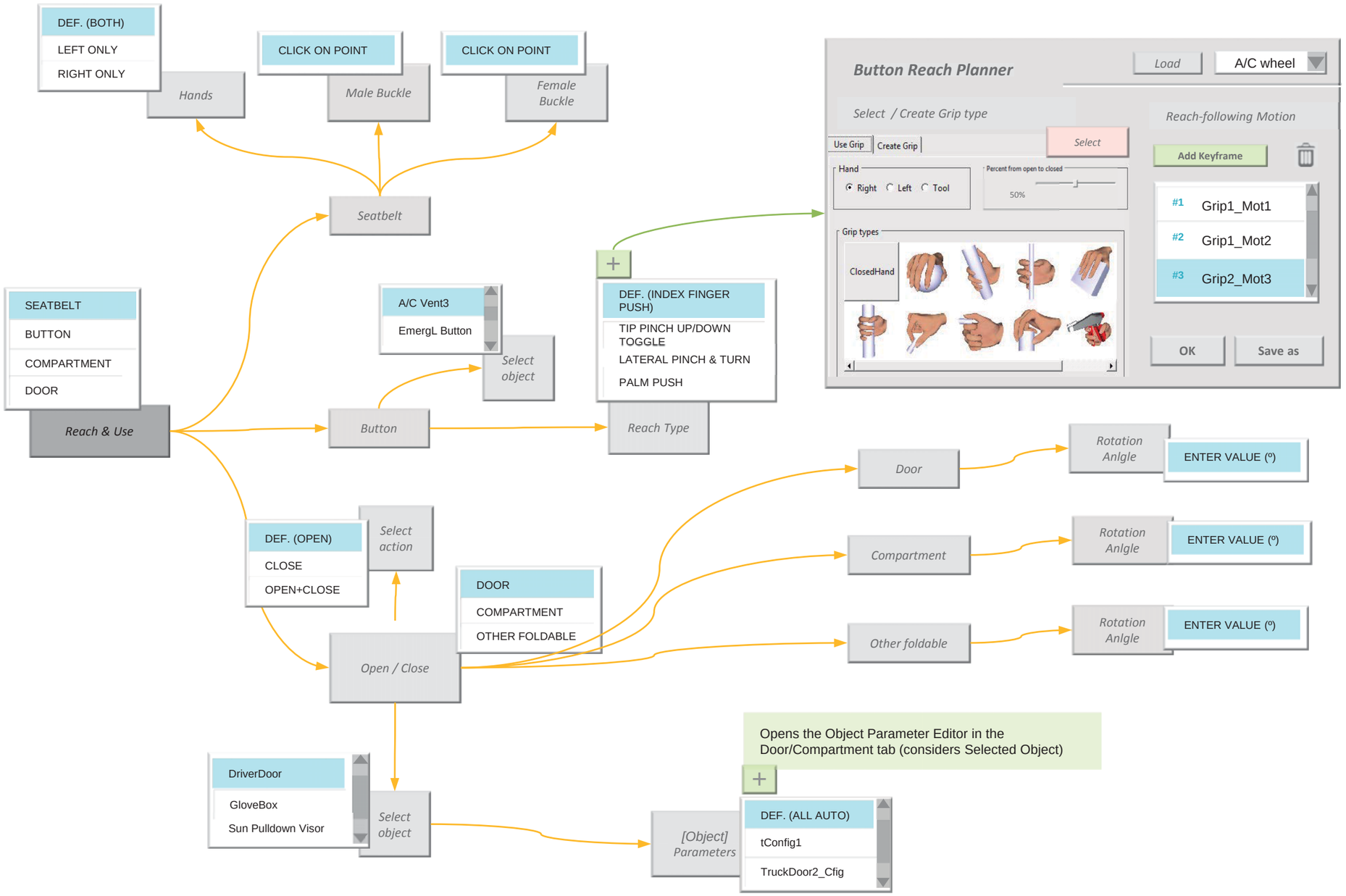


Default instruction. name: OperateJOYSTICK_CADfileName_##

When clicking "CLICK ON POINT", the scene will come visible and the user should click in the Male Buckle or Female Buckle where the motion should start and end respectively (the object doesn't move). Then, the manikin should generate a motion avoiding self- collision from male to female with the selected hand(s), being the second hand added to the motion at half-way in the case of two hands.

Default instruction. name: ReachUseSEATBELT_CADfileName_##

Default instruction. name: ReachUseBUTTON_CADfileName_##



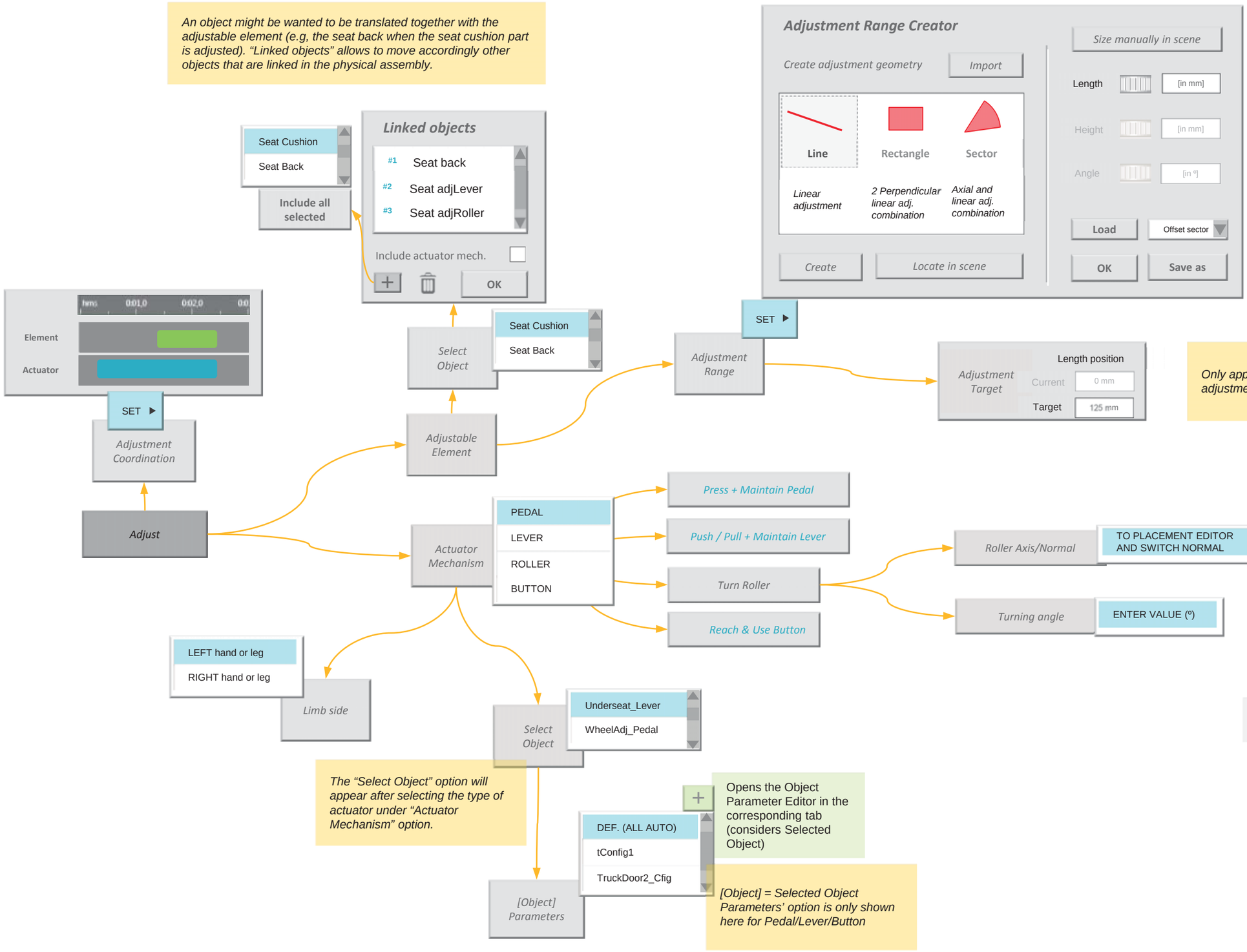
An object is selected together with a reach type. Reaches can also be generated through the Button Reach Planner, where:

1- A grip is selected (either default or created). The rest of preset reaches have a small motion automatically calculated considering the relative position to the manikin.

2- A subsequent action to the reach is designed through keyframes. When pressing the "Add Keyframe" button, the scene will come out with a grip edition (grip display + placement editor opened). Keyframe transitions can vary not only the position but also the Grip type, so for each Keyframe is the current selected Grip type that will be added.

Default instruction. name: OperateOPENCLOSE_CADfileName_##

An object might be wanted to be translated together with the adjustable element (e.g, the seat back when the seat cushion part is adjusted). "Linked objects" allows to move accordingly other objects that are linked in the physical assembly.



An object is selected together with an adjustment range geometry, which can be either loaded, imported or created, and then located and sized:

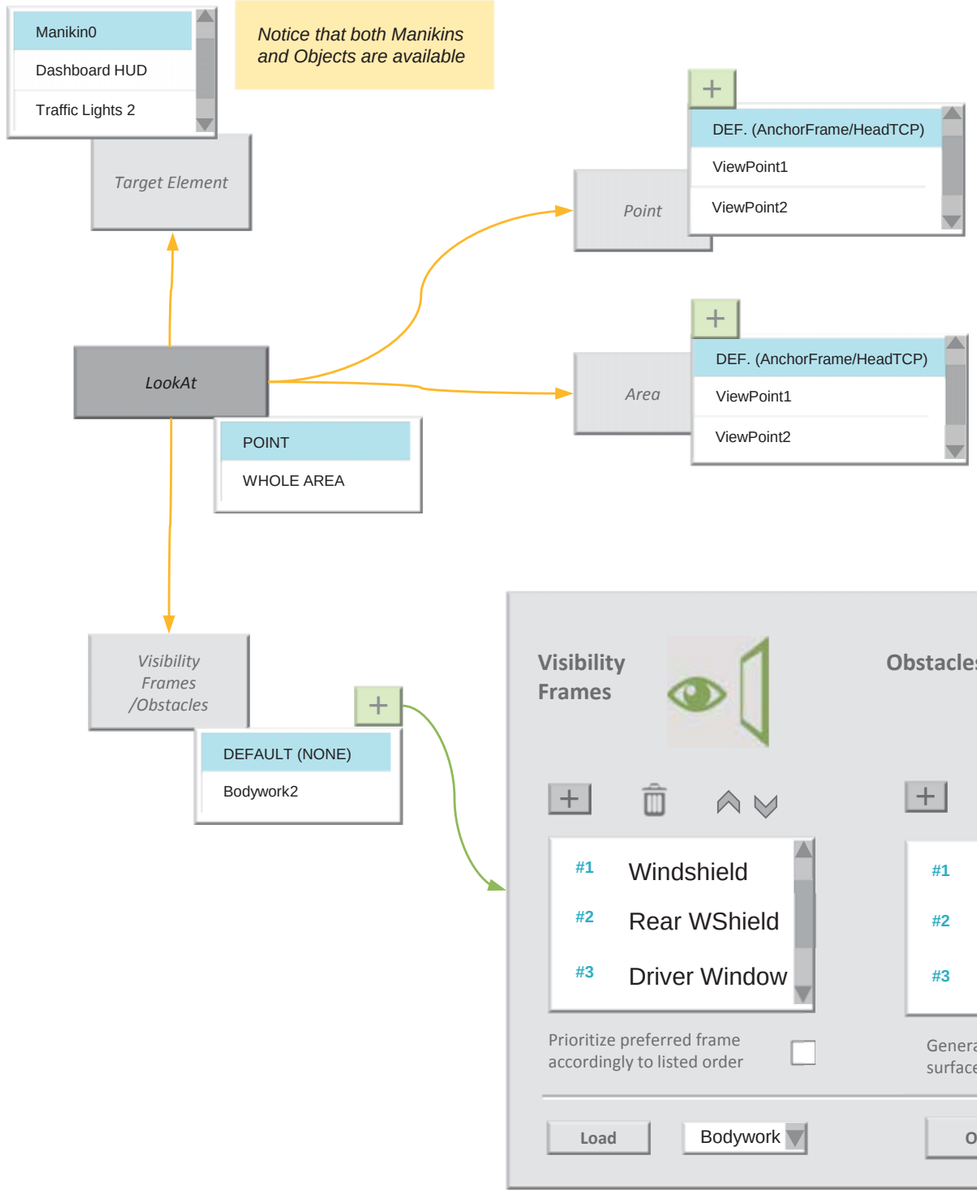
Only appears once the adjustment range is defined

The "Select Object" option will appear after selecting the type of actuator under "Actuator Mechanism" option.

Opens the Object Parameter Editor in the corresponding tab (considers Selected Object)

[Object] = Selected Object Parameters' option is only shown here for Pedal/Lever/Button

Default instruction. name: ADJUST_CADfileName_##



For some purposes, selecting a quite central point in some representative part of an object can be enough to guarantee visibility with fast calculations.

Other times, the instruction must guarantee that a whole area of an object is in the field of view of the Manikin (e.g., dashboard display), so the user should in a future be able to draw/project curves on surfaces to delimit that area.

Default instruction. name: LOOKAT_elementname_##

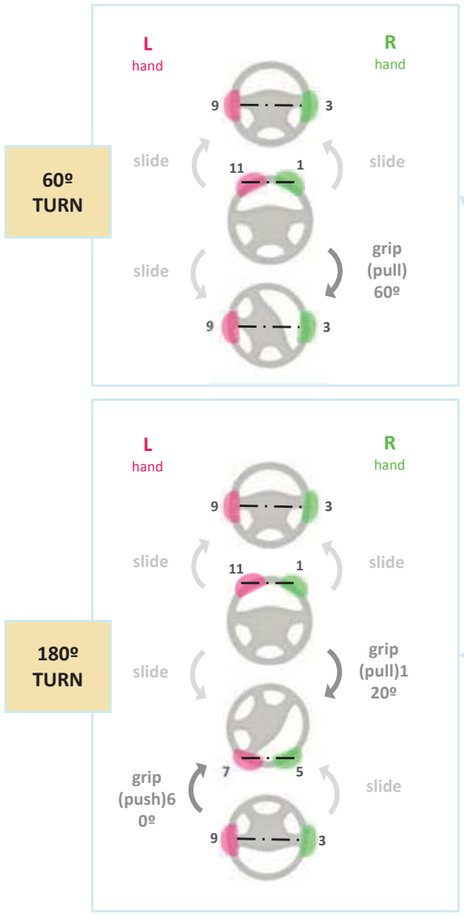
***Visibility frames** are preferred to obstacles when it comes to windows or any opening in a body where to look through., since obviously this will reduce possible solutions (i.e., calculations and therefore waiting time) significantly . When the software is developed enough, the user should be able, after clicking the add (+) button, to select edges of an object or project curves on surface (close contour(s)) that will encompass a single frame or set of frames through which the manikin will be constrained to look through.*

When there are several frames, the manikin would chose to look through the one that allows better posture among other constrains except if "Prioritize preferred farm accordingly to listed order" box is activated, which would ask for priority values that could interact with body in the body angle strategy criteria.

A modified copy of the Manikin's View Cone should be then generated, which would be cut by a new conic projection of the frame geometry away from the eye (having the eye-point as the projection source). If all the window is inside the original View Cone, this second View Cone would be entirely the one generated by the user defined frame geometry.

***Obstacles,** selected by the user after clicking the add (+) button, will make the manikin move so that its sight can avoid the objects that lay between it and the target element. As a general criteria, the side of the object that is nearer from the potentially blocked current direct sight will be tried first as obstacle avoidance. Obscuration zone surfaces will be generated if the corresponding box is checked.*

BASICS



*Clockwise examples

EASY + CORRECT PUSH / PULL

1- Recommended neutral/initial position : 9-3
+better against airbag (Daily Mail Reporter, 2012), better control and sense of current position & easier for IMMA as reference (start & end position)

2-Symmetry of hand position while steering
(hands should be same height all time)
+better sense of the current position & easier for IMMA to automate

3-Always start pulling down
+better control

DEFAULT TURNS: WHY 60º AND 180º TURNS?

Assuming all explained in the box above:

1- They allow ending in the initial 9-3 position.

2- It is the two minimum turns that fulfill reason (1-)

3- They are enough to test the whole range of movements possible in this steering modality.

Fitzpatrick (2011):
Correct Push/Pull Technique Video
https://www.youtube.com/watch?v=Lxa6lF-l13c

How would IMMA do it?

1- Basic Data Input (see Wheel parameters input and grips/paths in this section)

2- Two new grips are created in 11 and 1 position by just rotating the existing 9 and 3 grips around the wheel's Y axis.

3- Hands go to and grasp the grips 11 and 1 having first released 9 and 3 and following the Wrist TCP circumference.

Consider CW (right) turn now:

4- The non-gripping (left) hand is released.

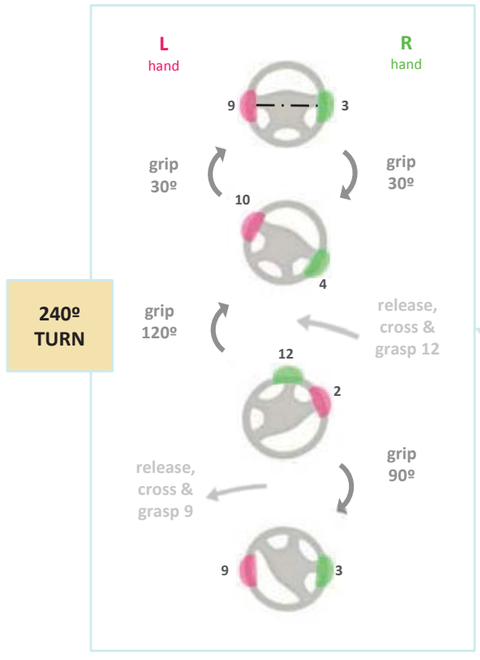
5- The wheel is turned 60º/120º CW, dragging the right grip with itself while the non-gripped left hand follows symmetrically. A grip is created in the resulting left hand's position

5- (following for 180º turn) the right grip is released.

6- The wheel is turned 60º dragging the left grip with itself while the non-gripped right hand follows symmetrically.

ALL THIS HAPPENS AUTOMATICALLY

BASICS



1- Recommended neutral/initial position : 9-3
+better against airbag (Daily Mail Reporter, 2012), better control and sense of current position & easier for IMMA as reference (start & end position)

2-This technique is recommended only for slow speeds and there are many variants, so some default that is enough to test some basics for this technique are suggested.

DEFAULT TURN: WHY 240º TURN?

Assuming all explained in the box above:

1- It allows ending in the initial 9-3 position.

2- It is the minimum turns that fulfill reason (1-)

3- It is enough to test the meaningful movements (i.e., crossing the arms) in this steering modality.

Igottadrive.com (2012):
Hand Over Hand example Video
https://www.youtube.com/watch?v=3G3MW2DEv3M

How would IMMA do it?

1- Basic Data Input (see Wheel parameters input and grips/paths in this section)

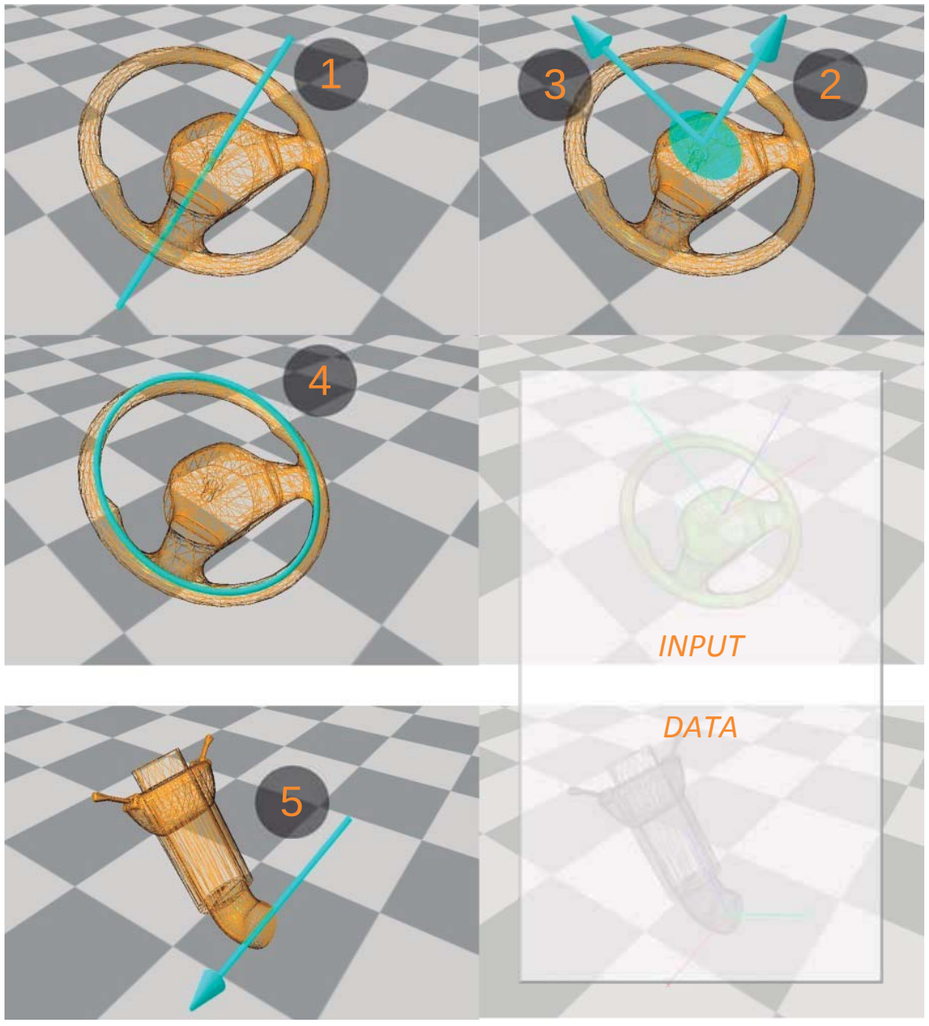
Consider CW (right) turn:

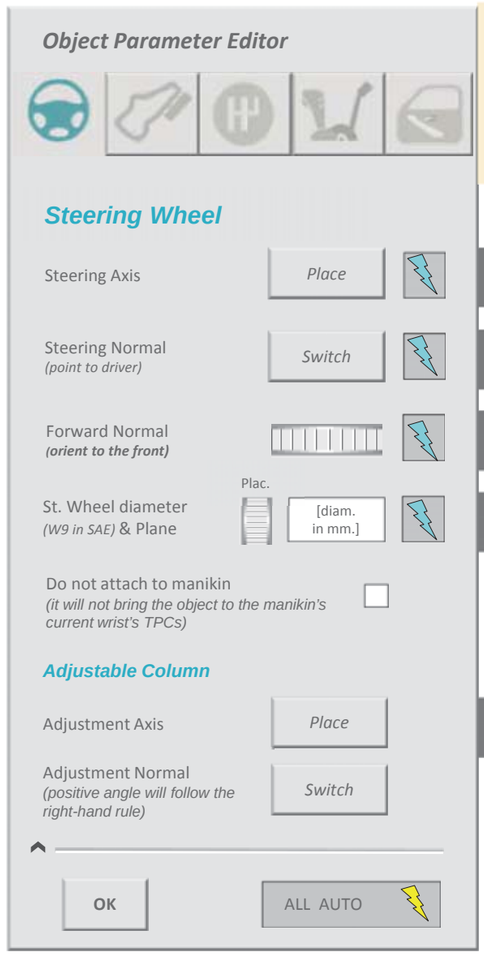
2- The wheel turns 30º with both grips grasped

3- The right grip is released. Then, the wheel turns 120º CW dragging the left hand (gripped) while the right hand is going to grasp a new grip in the 12 position in the end of the 120º turn.

4- The left grip is released. Right after, the wheel turns 90º CW dragging the right hand (gripped) and meanwhile the left hand heads to a new grip in the 9 position when the turn finishes.

ALL THIS HAPPENS AUTOMATICALLY





The OPE menu is accessible

a) Via the LIV menu when clicking Object Parameters
b) In the regular workflow clicking the correspondent button (out of the LIV)

1 *Opens the placement editor.*

2 *Switches the normal in the axis.*

3 *Orients the forward dir. around the previously defined normal.*

4 *Places the Wheel Plane perpendicular to and along the Steering Axis and sets the diameter for the steering wheel.*

5 *Opens the placement editor. This option will be ONLY AVAILABLE when the user previously selected an object as Adjustable Column in the LIV.*

INPUT DATA

It is the “raw” data that the program needs to work with, obtained out of the user input that is generated in the Object Parameters Editor.

CONSISTS OF**:**

✓ ***Wheel’s anchor frame (xyz), where***

+Y points to the “Forward Normal”
+Z points to the “Steering Normal”
The center is in the “Wheel Plane”

✓ ***Wrist TCP circumference****:*

This will be created revolving either wrist TCP (as located ***here***), around the anchor frame’s Y axis.

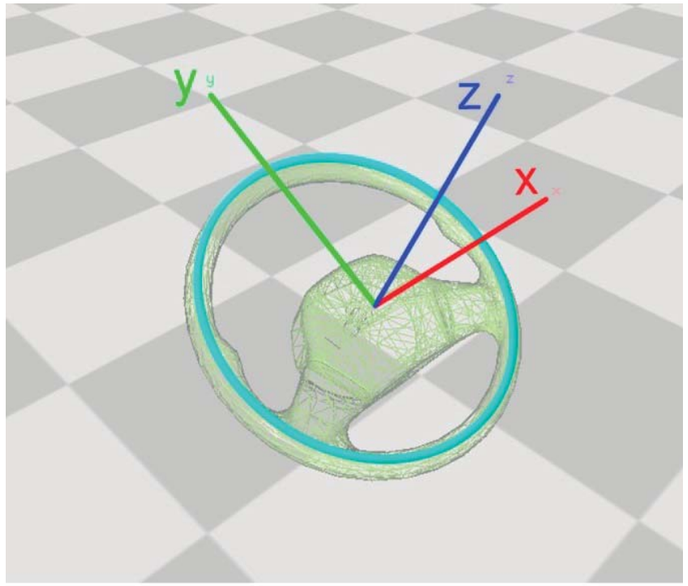
✓ ***9-3 Grips:***

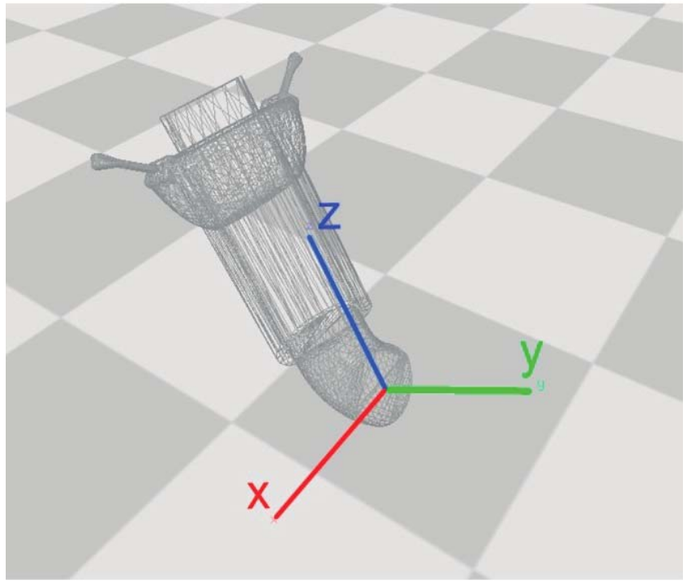
Automatically generated (***explanation here***)

✓ ***Adjustment axis:***

+X points the Adjustment Normal

As generated by the user whenever an adjustable column is selected in the LIV





9-3 GRIPS

Grips in 9-3 position are automatically generated with experts criteria in relation to the previous parameters. This is how the program would work with the data, to completely place both grips (with some suggested angles for cars. There should be a default for each vehicle type associated with the posture strategy):

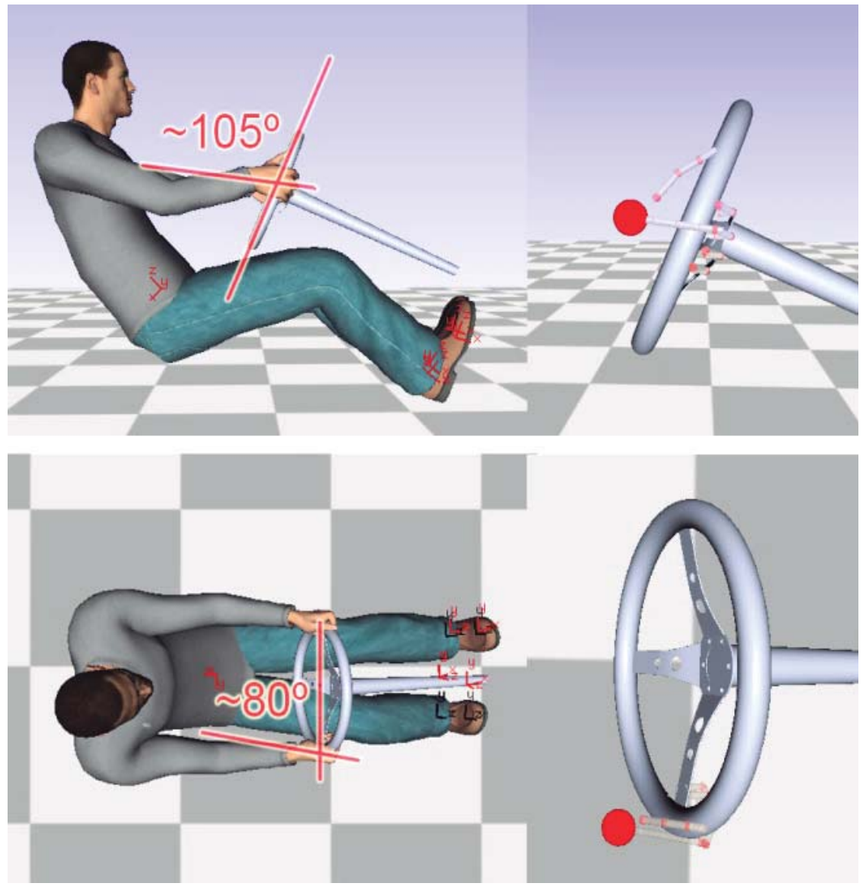
105º (or expert's value) for the angle in the +Y side between:

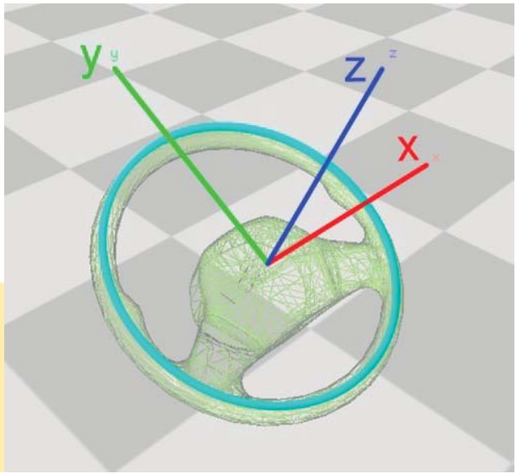
a) *The palm's segment projection in the YZ plane*
b) *The XY plane*

85º (or experts value) for the angle in the closer side to the anchor frames' center between:

a) *The palm's segment projection in the XZ plane*
b) *The XY plane*

Grip's TCPs in the XZ plane, at around 30 mm away of the XY plane :

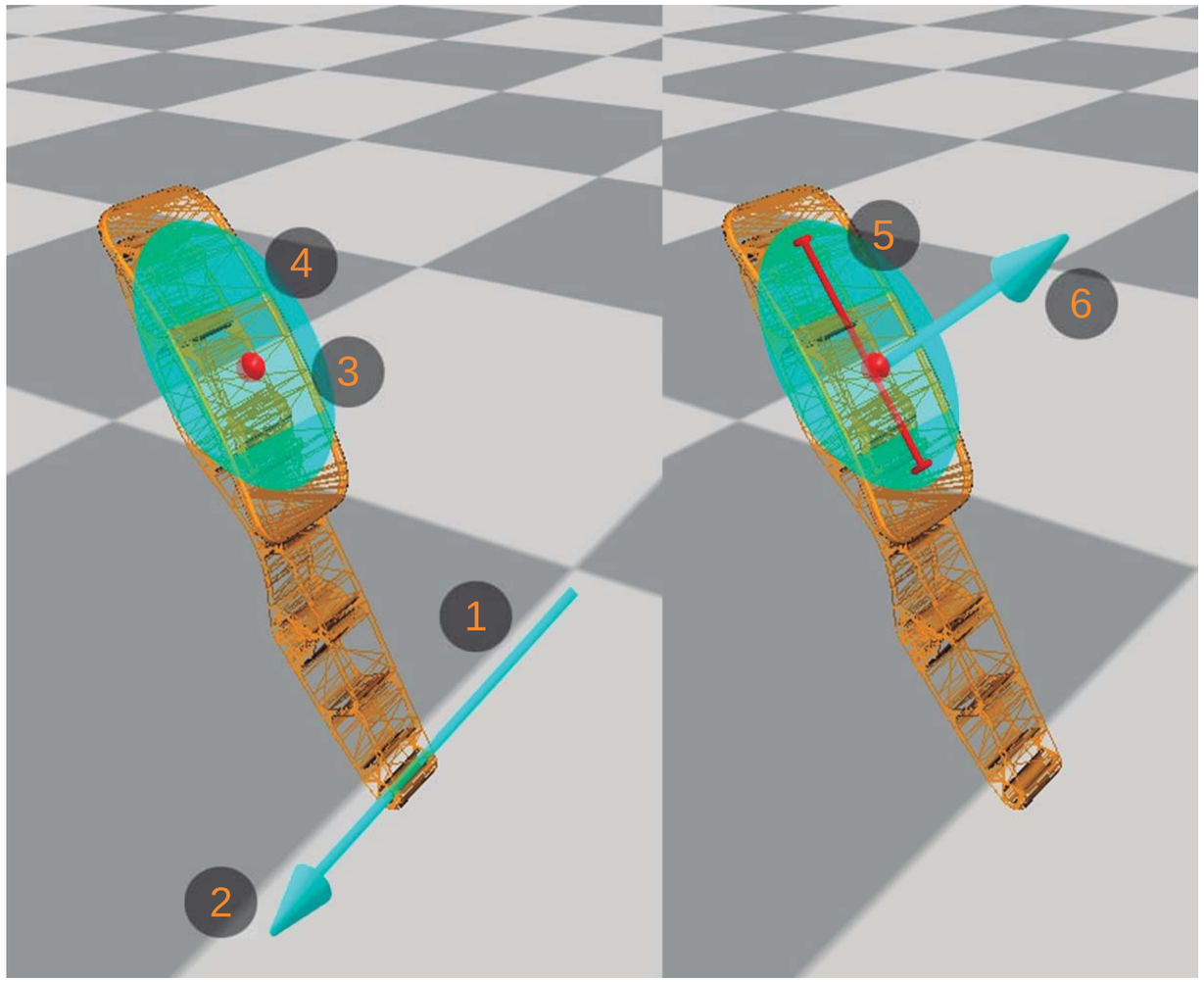


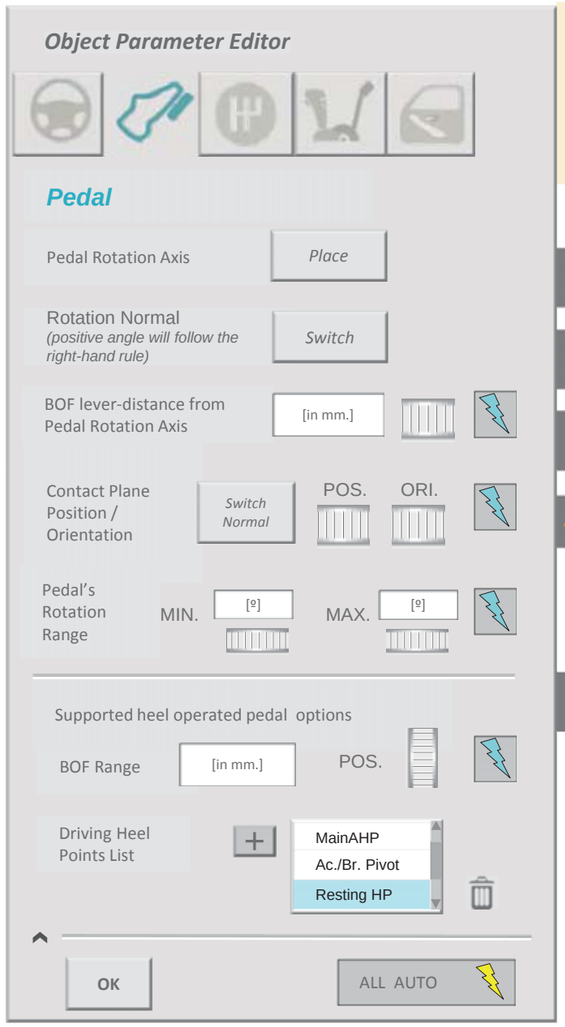


***IMPORTANT NOTE**:*

All references to X,Y and Z axes or derived planes refer to the "INPUT DATA" generated for the wheel.

NOTE: the angle was measured from wheel's anchor frame's XY plane projection (not exactly the current view), which is needed for the correct data computation.





The OPE menu is accessible

a) Via the LIV menu when clicking Object Parameters
b) In the regular workflow clicking the correspondent button (out of the LIV)

1 *Opens the placement editor.*

2 *Switches the normal in the axis.*

3

4-5 *-Adjusts the gap of the Contact Plane to the Rotation Axis.*
-Orients the Contact Plane around the Pedal Rotation Axis.

6 *Sets a Ball of Foot line range so that the BOF of the manikin can glide along it freely when a pedal is heel supported and the manikin is told to press it.*

The range can be moved around the initial BOF point (notice that depending if the axis is above or below the Contact Plane, the first contact will be produced in the higher or lower point of the range respectively.

INPUT DATA

It is the “raw” data that the program needs to work with, obtained out of the user input that is generated in the Object Parameters Editor.

CONSISTS OF**:**

✓ ***Pedal’s anchor frame (xyz), where***

+Y points to the “Contact Plane Normal”
+Z points to the (“Pedal Rotation Axis” to “BOF” direction)
The center is at the “Pedal Rotation Axis”

✓ ***BOF (Ball Of Foot)****:*

It represents the initial point where the BOF touches the pedal or the only point when there are unsupported heel instructions.

✓ ***BOF Range:***

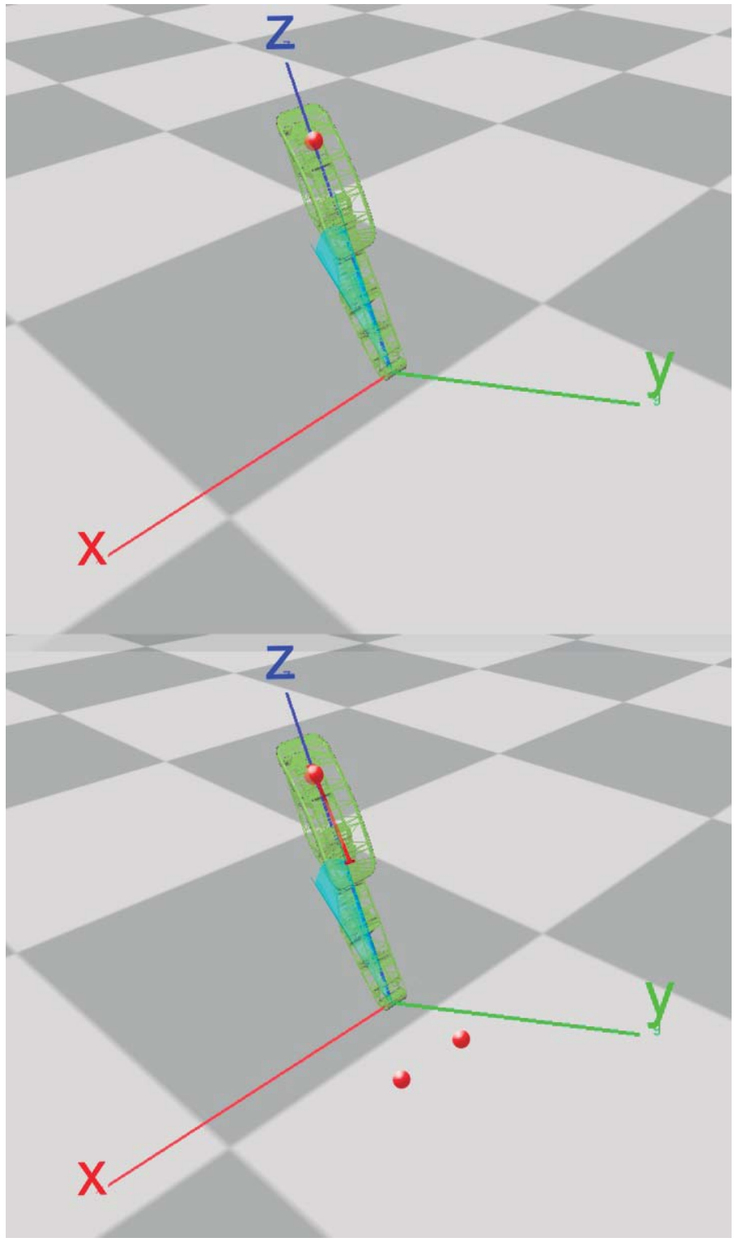
Parallel to Z axis and determined by user in mm and position in relation to the BOF.

✓ ***Pedal’s Rotation Range:***

Angle range starting from Z, being the positive user entered numbers following the right-hand rule around the X axis.

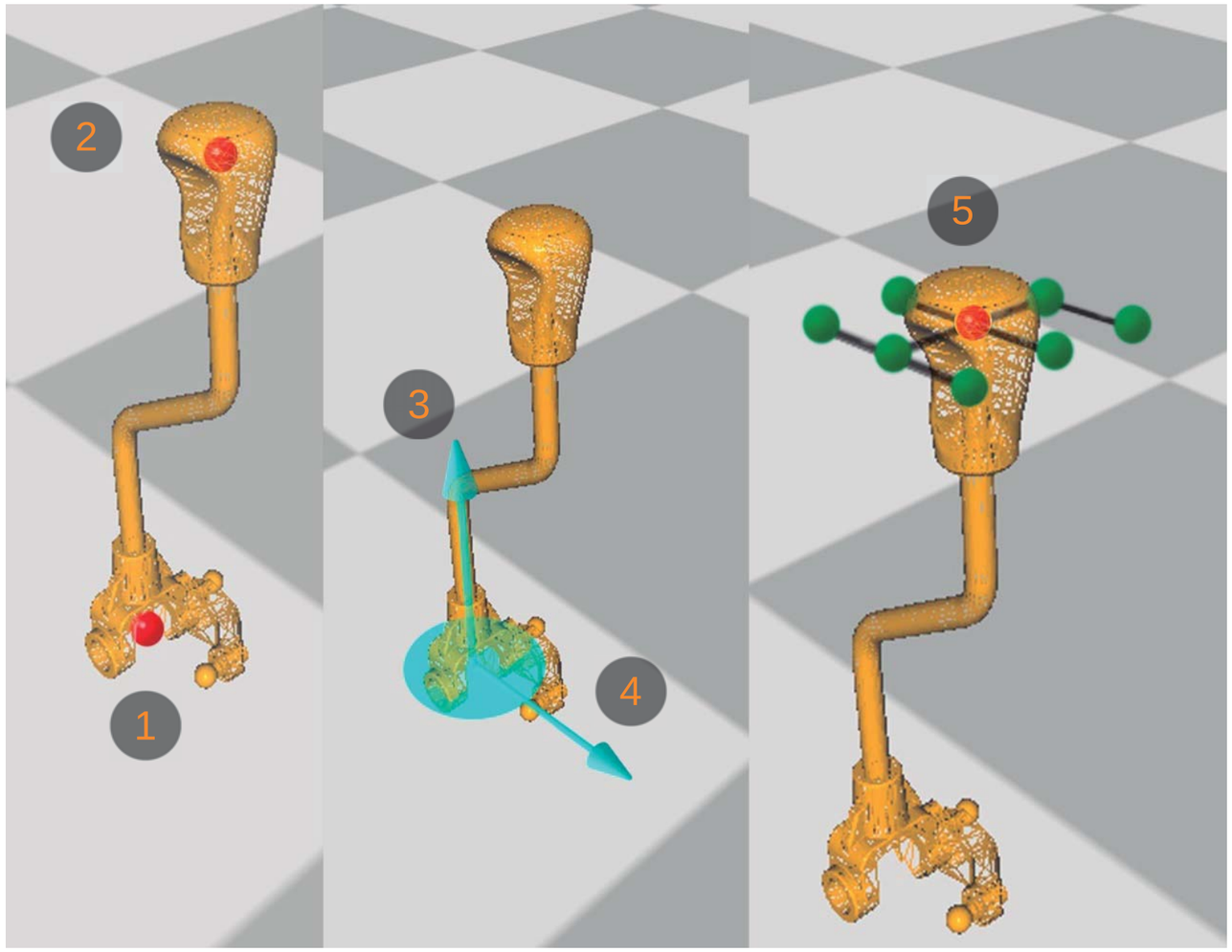
✓ ***Driving Heel Points***

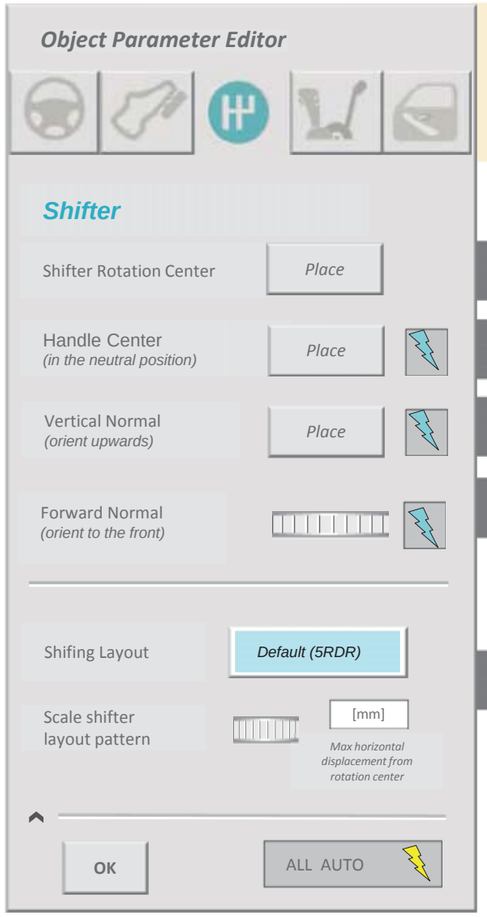
As defined by user and included in the list to be available as Heel Points in a Drive Pedal instruction



Data for UNSUPPORTED HEEL instructions

Data for SUPPORTED HEEL instructions





The OPE menu is accessible

a) Via the LIV menu when clicking Object Parameters

b) In the regular workflow clicking the correspondent button (out of the LIV)

1

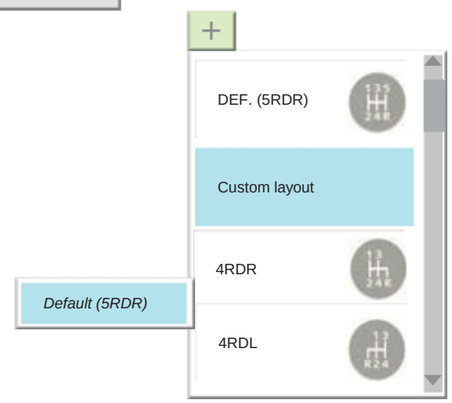
2 *Open the Placement Editor.*

3

4 *Orients the Forward Normal around the Vertical normal*

5 *-Allows selecting between different shifting patterns or creating new ones. Reference points will be generated.*

-Scales the Shifting Layout around the neutral (N) point or Handle Center.



INPUT DATA

It is the “raw” data that the program needs to work with, obtained out of the user input that is generated in the Object Parameters Editor.

CONSISTS OF**:**

✓ ***Shifter’s anchor frame (xyz), where***

+Y points to the “Forward Normal”
+Z points to the “Vertical Normal”
The center is at the “Shifter Rotation Center”

✓ ***Handle Center***

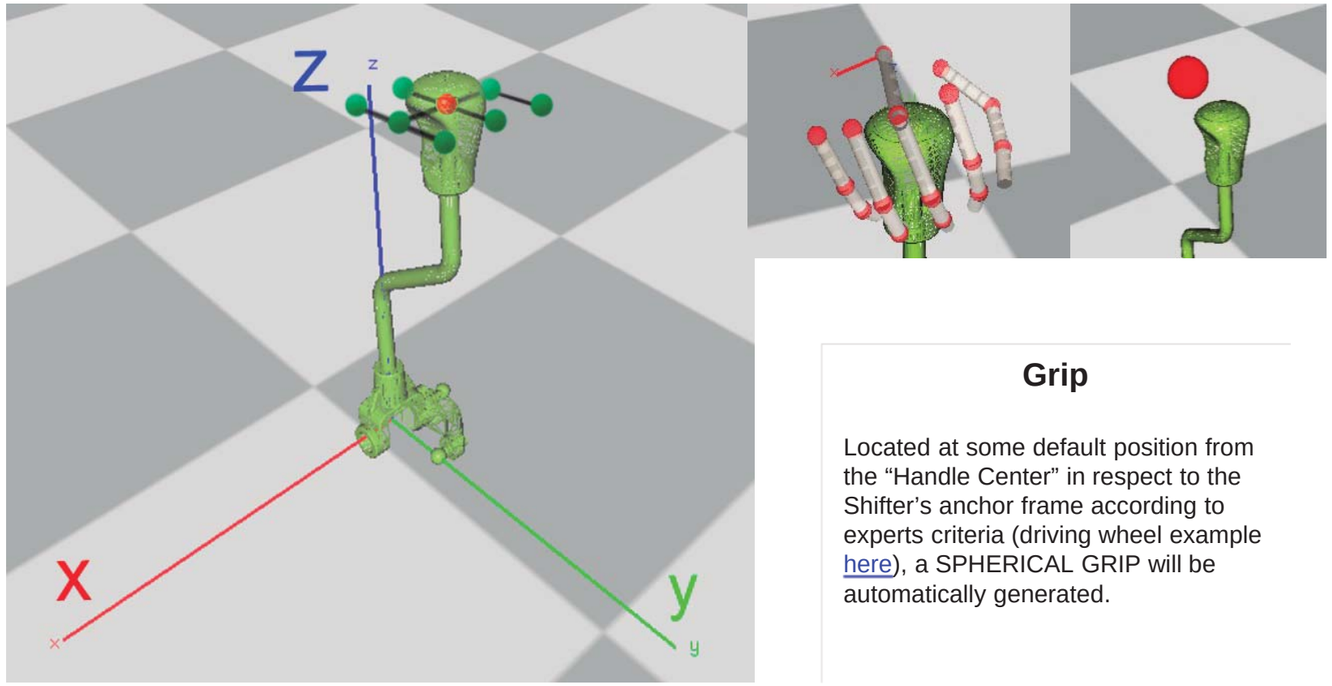
It represents the central point of the handle, where the N (neutral) position reference is set for the Shifting Layout.

✓ ***Shifting Layout Points and Paths***

A bunch of reference points located as guided by the selected Shifting Layout. These points will allow generating paths from one gear to another depending on the instructions, always passing through the neutral point.

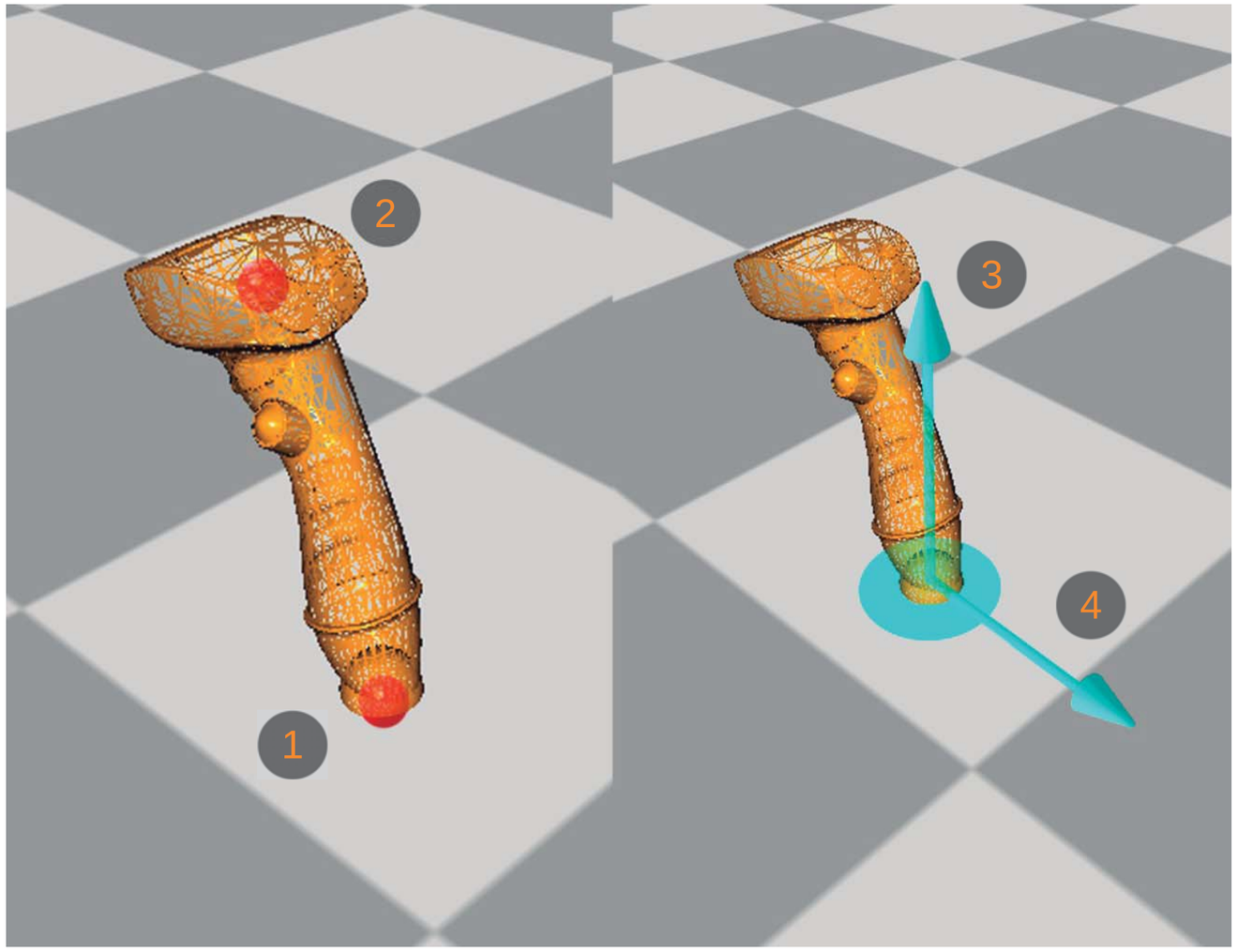
✓ ***Handle Grip:***

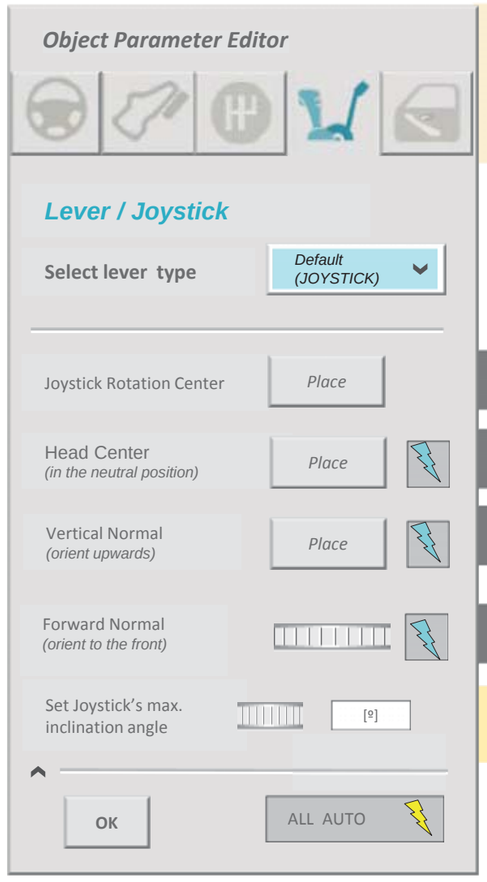
Automatically generated (***explanation under the right side picture)***



Grip

Located at some default position from the “Handle Center” in respect to the Shifter’s anchor frame according to experts criteria (driving wheel example here), a SPHERICAL GRIP will be automatically generated.





The OPE menu is accessible

a) Via the LIV menu when clicking Object Parameters
b) In the regular workflow clicking the correspondent button (out of the LIV)

1

2 *Open the Placement Editor.*

3

4 *Orients the Forward Normal around the Vertical normal*

Sets a maximum Joystick inclination angle boundary all around.

INPUT DATA

It is the “raw” data that the program needs to work with, obtained out of the user input that is generated in the Object Parameters Editor.

CONSISTS OF**:**

✓ ***Joystick’s anchor frame (xyz), where***

+Y points to the “Forward Normal”
+Z points to the “Vertical Normal”
The center is at the “Joystick Rotation Center”

✓ ***Handle Center***

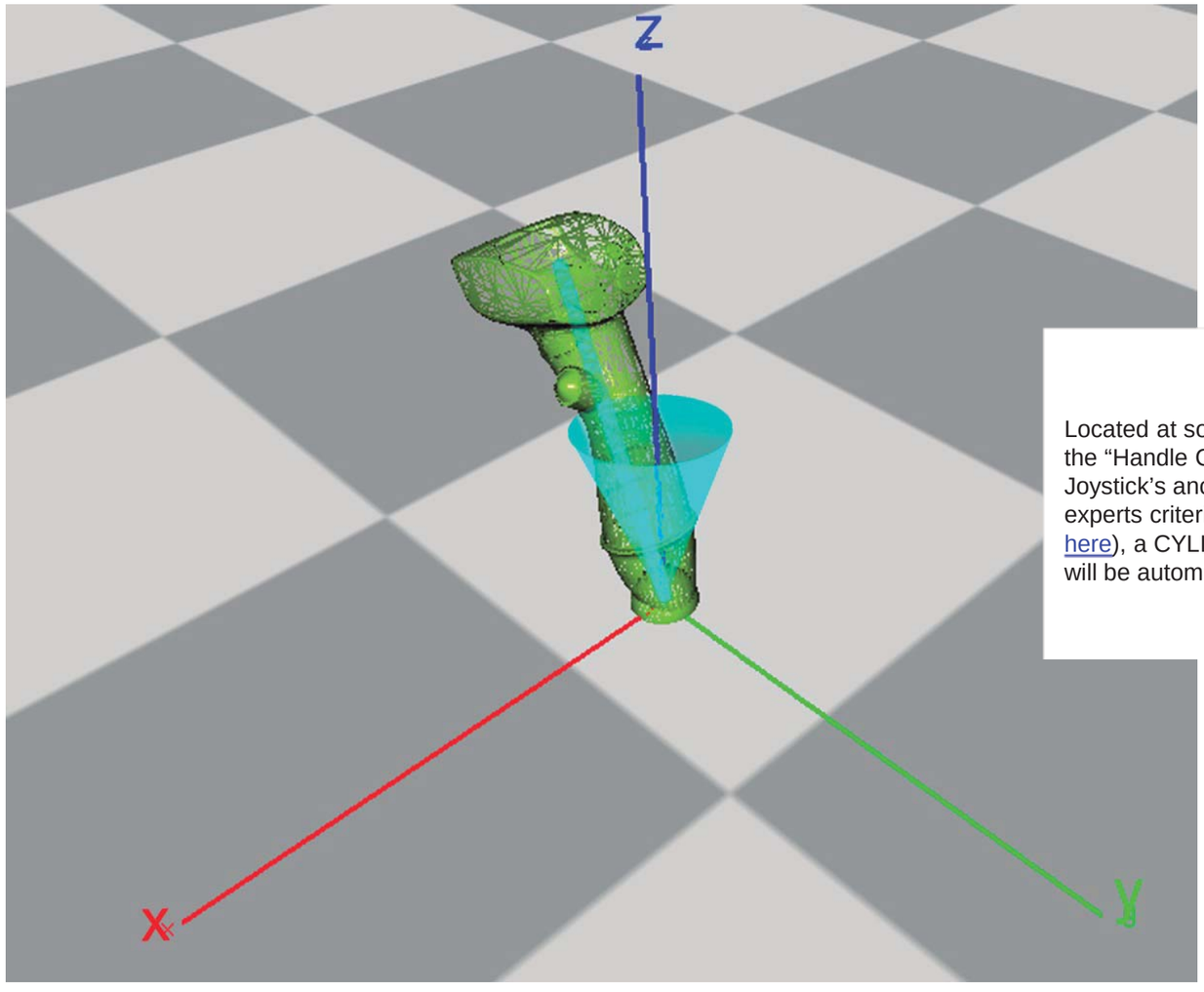
It is an automatically generated middle point between the “Joystick Rotation Center” and the “Head Center”.

✓ ***Inclination limit cone***

Automatically generated upside down cone, with the entered slope angle. Its tip is at the anchor frame center. The base of the cone is perpendicular to the Z axis.

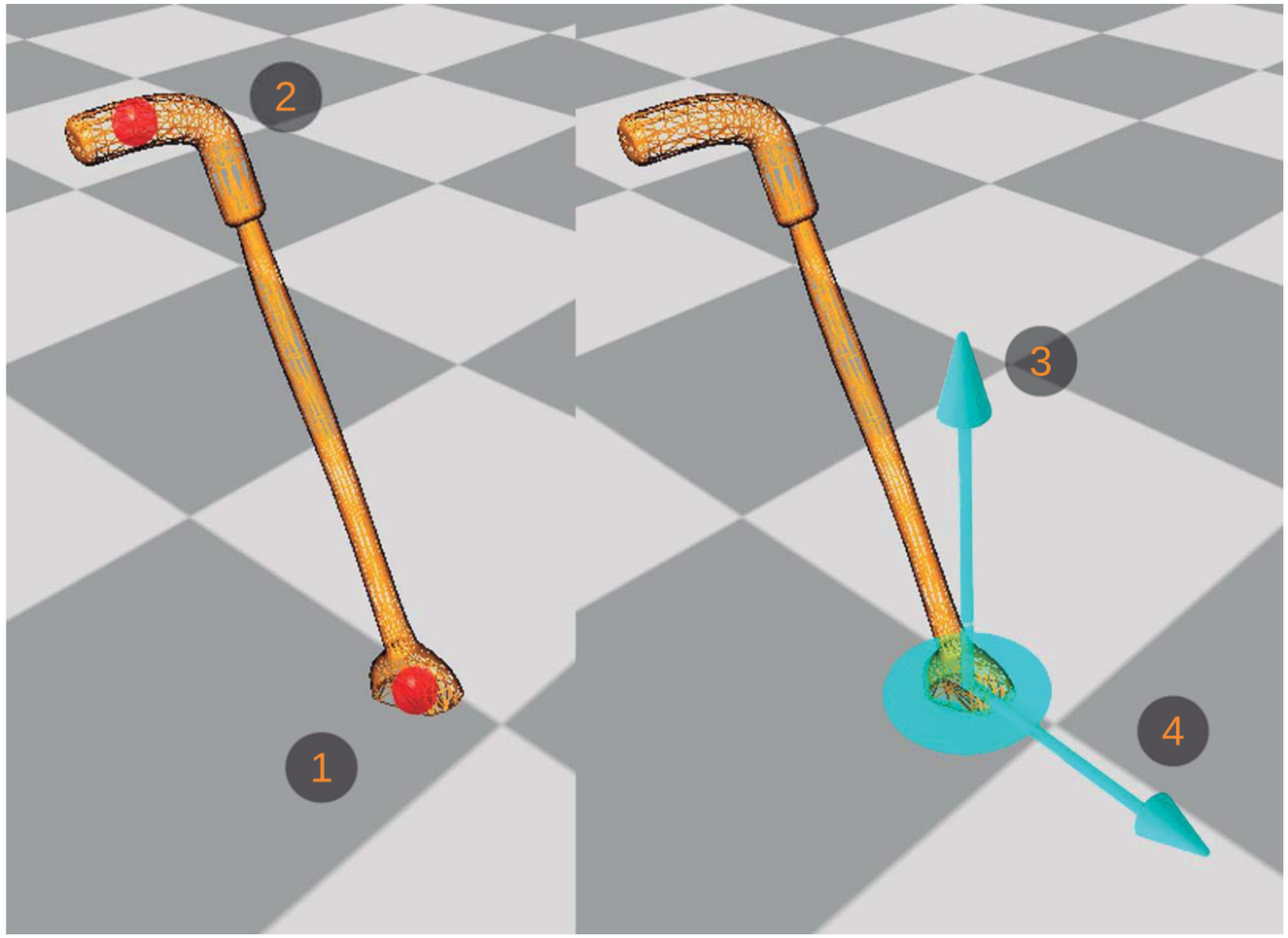
✓ ***Handle Grip:***

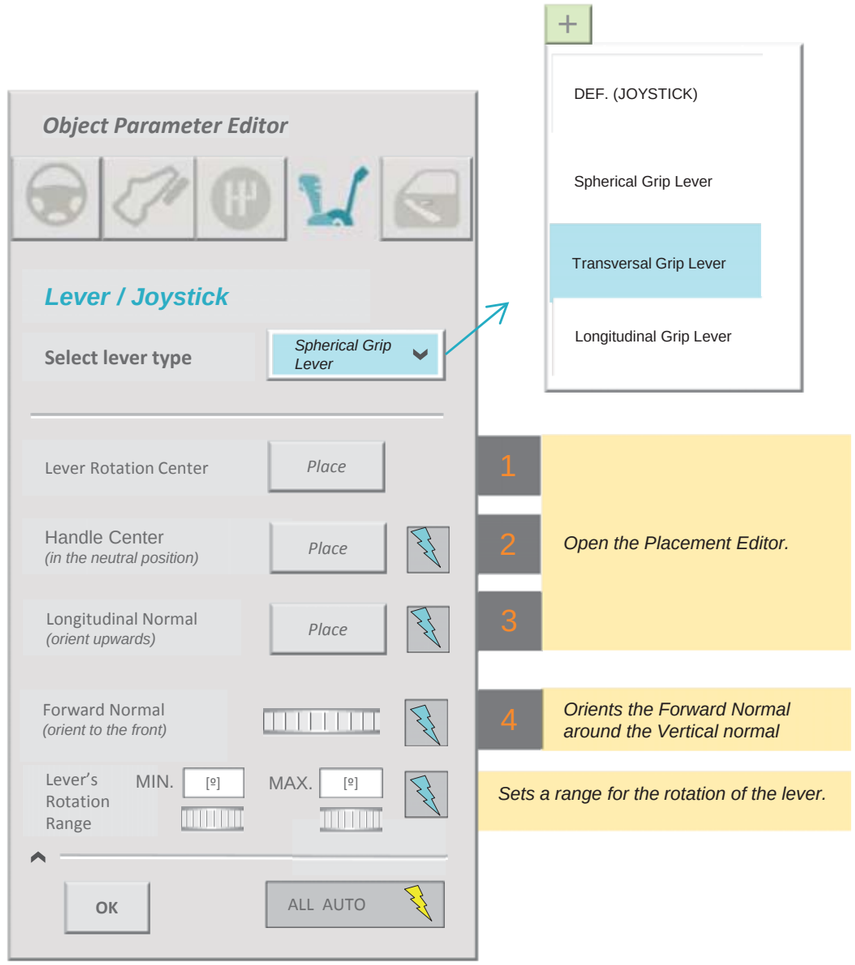
Automatically generated (***explanation under the right side picture)***



Grip

Located at some default position from the “Handle Center” in respect to the Joystick’s anchor frame according to experts criteria (driving wheel example here), a CYLINDRICAL POWER GRIP will be automatically generated.


2
3
1
4


Object Parameter Editor
Lever / Joystick
Select lever type
Spherical Grip Lever
Lever Rotation Center
Place
Handle Center
(in the neutral position)
Place
Longitudinal Normal
(orient upwards)
Place
Forward Normal
(orient to the front)
Lever's Rotation Range
MIN.
[º]
MAX.
[º]
OK
ALL AUTO
+
DEF. (JOYSTICK)
Spherical Grip Lever
Transversal Grip Lever
Longitudinal Grip Lever
1
2
Open the Placement Editor.
3
4
Orients the Forward Normal around the Vertical normal
Sets a range for the rotation of the lever.

INPUT DATA

It is the “raw” data that the program needs to work with, obtained out of the user input that is generated in the Object Parameters Editor.

CONSISTS OF**:**

✓ ***Lever’s anchor frame (xyz), where***

+Y points to the “Forward Normal”
+Z points to the “Vertical Normal”
The center is at the “Joystick Rotation Center”

✓ ***Handle Center***

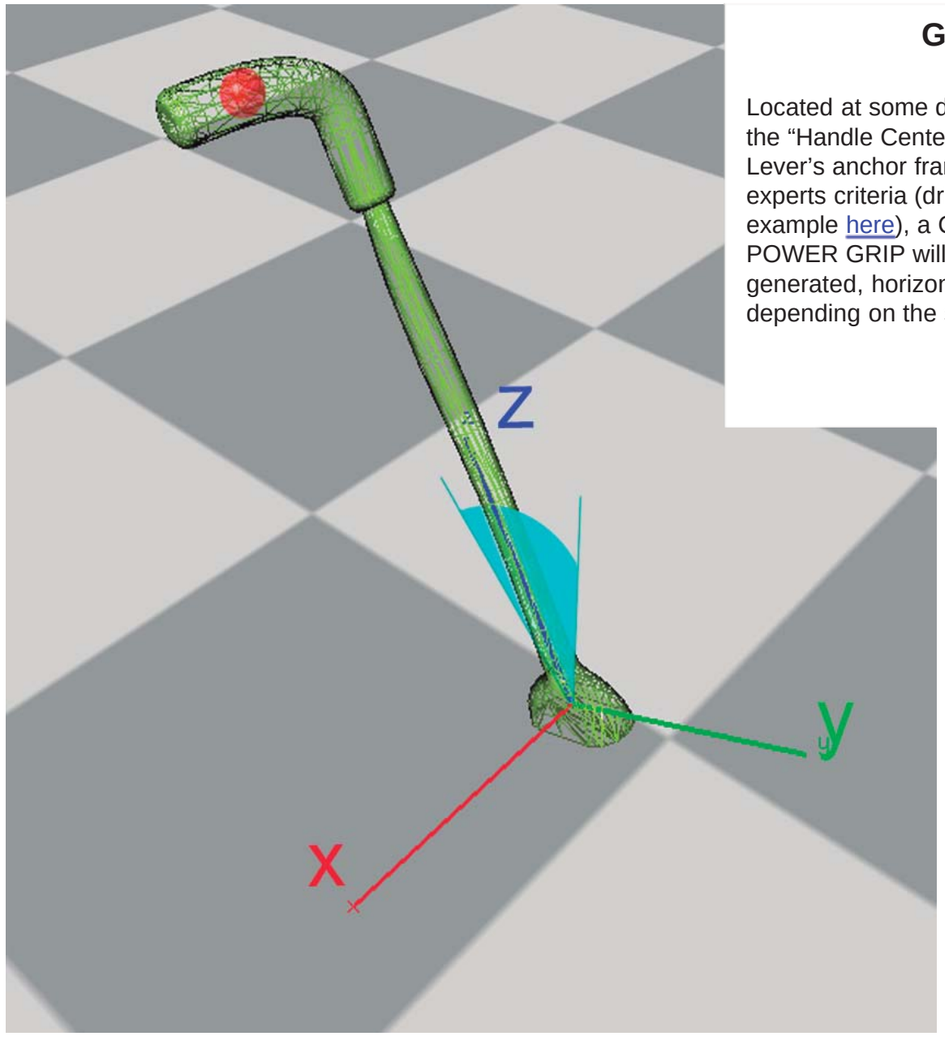
It is an automatically generated middle point between the “Lever Rotation Center” and the “Head Center”.

✓ ***Lever’s Rotation Range:***

Angle range starting from Z, being the positive user entered numbers following the right-hand rule around X axis.

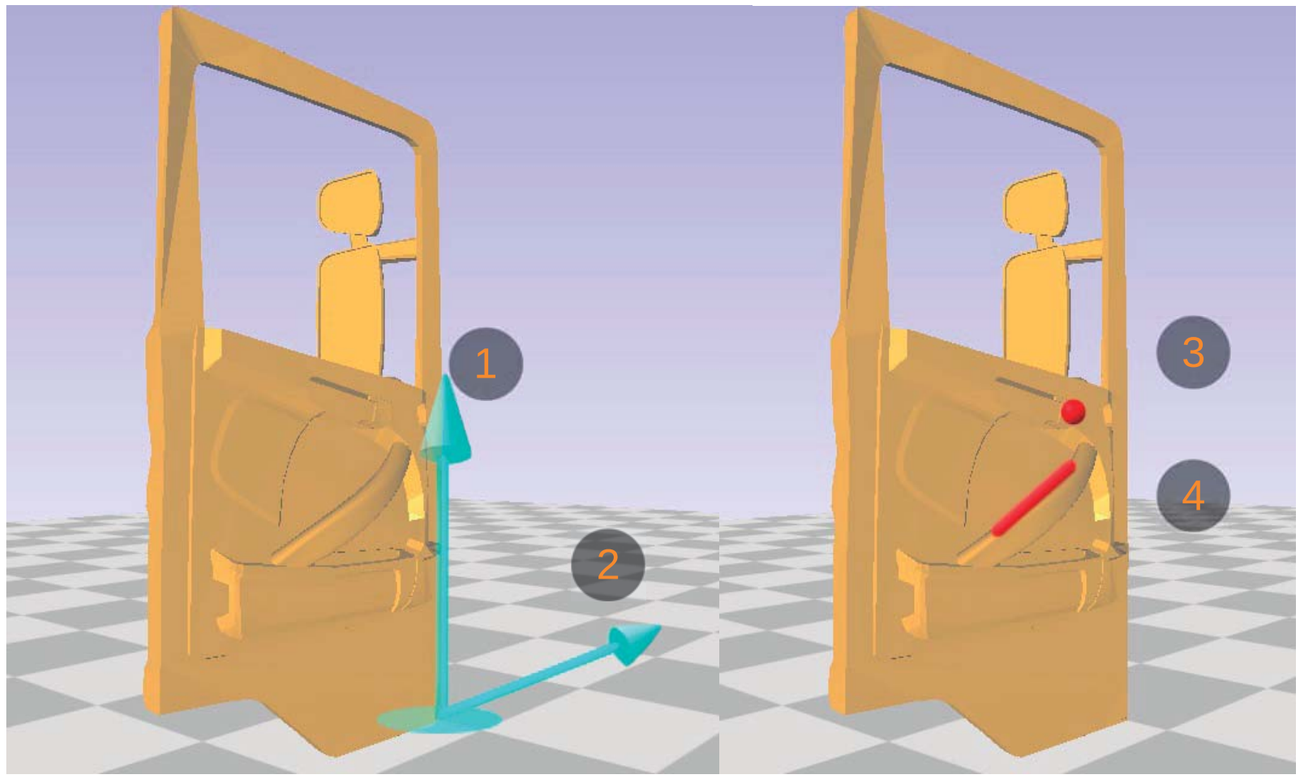
✓ ***Handle Grip:***

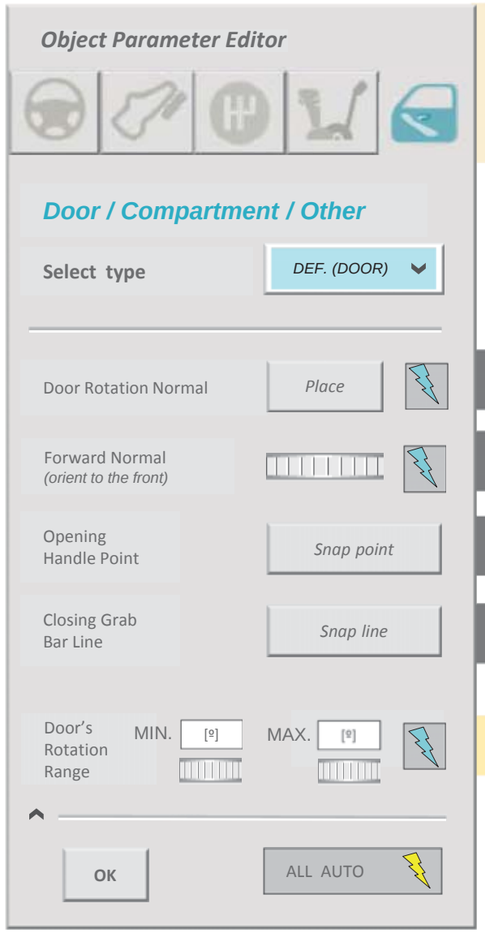
Automatically generated (***explanation under the right side picture)***



Grip

Located at some default position from the “Handle Center” in respect to the Lever’s anchor frame according to experts criteria (driving wheel example here), a CYLINDRICAL POWER GRIP will be automatically generated, horizontal or vertical depending on the selected lever type.





The OPE menu is accessible

a) Via the LIV menu when clicking Object Parameters

b) In the regular workflow clicking the correspondent button (out of the LIV)

1 *Open the Placement Editor.*

2 *Switches the normal*

3 *Uses a point of the model (user clicked) surface as reference.*

4 *Creates a line between two user selected points in the surface.*

Sets a range for the rotation of the door.

INPUT DATA

It is the “raw” data that the program needs to work with, obtained out of the user input that is generated in the Object Parameters Editor.

CONSISTS OF**:**

- ✓ ***Door’s anchor frame (xyz), where***

+X points to the “Forward Normal”
+Z points to the “Door Rotation Normal”
The center is at the “Joystick Rotation Center”

- ✓ ***Opening Handle Grip***

Automatically generated:
At some default distance and orientation determined by experts (example with driving wheel here) from the Opening Handle in relation to the Door’s anchor frame

- ✓ ***Grab Bar Grip***

Automatically generated:
At some default distance and orientation determined by experts (example with driving wheel here) from the center of the Closing Grab Bar line in relation to the Door’s anchor frame